# The TREND IN ENGINEERING

## at the University of Washington

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- Environmental Research Laboratory
- University's Analog Computer
- Fifth Road-Building Conference
- Some Properties of Triethylene Glycol Lignin
- Recording Interferometer
- Wireless Lapel Microphone
- Research on Swept Wings
- Mass Spectrometer in Use at University
- Mining Institute Holds Meeting
- Liquid-Liquid Extraction



*April, 1952*

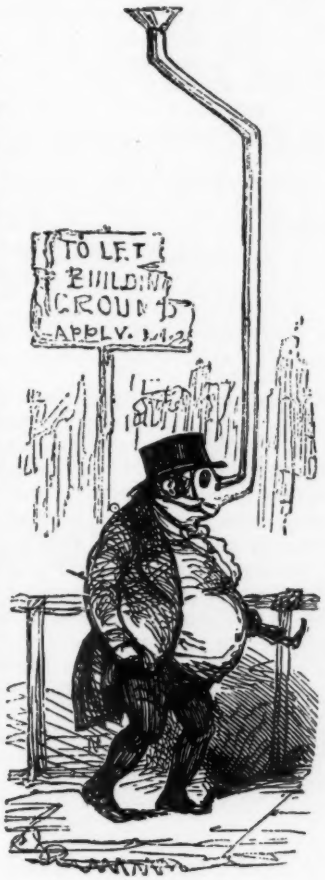
VOL. 4, No. 2

# *Punch's* 1849 Satire on Air Pollution

## NEW USE FOR GUTTA PERCHA.

In addition to drinking-cups, driving-bands, whips, hats, splints, portable soup, shoes, elastic heads, coats, candles, tubing, tenpenny nails, theatrical banquets, picture-frames, saveloys, buttons, baskets, biscuits, and other various forms into which that universal material Gutta Percha has been converted, we beg to suggest a new and sanitary employment from this multiform substance, to which its connexion with the gutter would seem naturally to adapt it.

We would suggest that masks with pipes of Gutta Percha might be employed in London and other large towns, for enabling the wearer to breathe the upper and purer currents of air, in the neighbourhood of our slaughter-houses, cattle markets, graveyards, bone-boilers', soap-makers', and cat-gut manufacturers'. Without some such arrangement we do not see how the Londoner is to enjoy the "sweet airs that give delight and hurt not" which we are assured by philosophers *do* exist somewhere above our heads, and of which we may be allowed to breathe the name, if we cannot breathe any more substantial part of them.

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THE ENGINEERING EXPERIMENT STATION of the University of Washington was established in December, 1917, to coordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

The scope of the work is three-fold:

(1) to investigate and publish information concerning engineering problems of a more or less general nature that would be helpful in municipal, rural, and industrial affairs;
(2) to undertake extended research and to publish reports on engineering and scientific problems;
(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

For administrative purposes the work of the Station is organized into nine divisions:

1. Aeronautical Engineering
2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgy, Ceramics
9. Physics Standards and Tests

The control of the Station is vested in a Station Board consisting of the President of the University, the Dean of the College of Engineering as chairman, the Director of the Station, and members of the faculty, representative of the administrative divisions. The Board determines the character of the investigations to be undertaken and supervises the work.

The Station offers a substantial number of research fellowships to highly qualified graduate students who work under the direct supervision of the faculty of the various divisions. The results of the investigations are published in the form of bulletins, technical notes, and reports. Reprints of articles by members of the engineering faculty and graduate students published in recognized technical journals are also issued by the Station. Requests for copies of the publications and inquiries for information on engineering and industrial problems should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

April, 1952

# The TREND

IN ENGINEERING

at the University of Washington

Vol. 4 No. 2

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### COVER

Roy A. Veldee, Engineering Experiment Station Research Fellow in the Environmental Research Laboratory, is shown with the apparatus for determining fluorides by the modified Willard-Winter distillation method.

ROAD BUILDERS OF 1952

*Top*

*Left:* Mrs. Julia B. Hansen
*Center:* E. V. Miller, W. C. Williams
*Right:* M. P. Coopey

*Upper Center*

*Left:* F. G. Redman, R. B. Van Horn, W. A. Bugge
*Right:* G. R. Egan, A. S. Wellborn, Dean H. E. Wessman

*Lower Center*

*Left:* R. H. Meese, G. B. Bennett, B. R. Bertramson, L. H. Morgan
*Right:* W. F. Winters

*Below*

*L. to r.:* C. E. Fritts, G. A. Riedesel, Willa W. Mylroie, R. G. Hennes

# The Environmental Research Laboratory

ROSS N. KUSIAN
*Acting Director of the Laboratory*

R. N. Kusian

The activities of the Environmental Research Laboratory at the University of Washington intersect more technical fields than those of possibly any other industrial or academic research agency. From launching a weather balloon to injecting dust into a rat's lungs, the Laboratory is prepared to carry on investigations into the effects of man's physical environment.

Administration of the Laboratory, a problem in itself because it requires proficiency in medicine, engineering, chemistry, toxicology, and meteorology, is carried on by a committee of representatives from the related departments, who establish the general policies of the Laboratory. Active administration is a joint concern; medical problems are handled by a physician on the staff, while technical administrative details are referred to an engineer.

### Atmospheric Pollution

Staff members are invariably asked about the type of work done by the Laboratory whose name does not completely convey its function. One of the first contracts received was for an atmospheric pollution study of the city of Seattle which has no ordinance controlling the emission of pollutants.

During 1949 and 1950 Alvin W. Green, Assistant Professor of Public Health and Preventive Medicine, had pioneered detailed studies of atmospheric pollution in the Lake Washington ship-canal trough, a region virtually bisecting Seattle. On the basis of Professor Green's report submitted to the University of Washington's atmospheric pollution committee, the city of Seattle authorized a city-wide study.

Professor Green had found a great need for standardized sampling and analytical procedures. Relatively simple methods were needed to measure the actual amount of dust-fall, amount of air-borne dust that was too fine to settle, amount of sunshine lost, loss of visibility, damage to painted surfaces, levels of dusts polluted with radioactive substances, amount of harmful gases, etc. Although other cities had made similar surveys, local conditions such as topography, types of industries, and weather conditions, introduced many additional variables to the methods previously used.

In other areas dust-fall jars are used as a means to indicate dirtiness of the region. In order to obtain comparative values for Seattle, dust-fall jars were placed at 27 selected locations throughout the city. Selection of these locations alone constituted a major problem since typical residential and industrial areas needed to be averaged. If industrial areas were favored, the results would be too high. Also, the jars had to be located on the roof tops in such a way as to avoid swirling of the wind which could easily distort the amount of settled dust.

Other variables had to be taken into account. Consider the effect of a bird regularly roosting on the edge of a jar when the deposit of this 14 square-inch jar is translated into tons of deposited dirt per square mile per month!

It is thus apparent that use of the dust-fall jar is far from a scientific procedure. Nevertheless, the value of comparison with other areas using the same method outweighed its unscientific aspects, and the tests were put into operation.

During the summer quarter several inches of distilled water were put in the jars as they were set out in order to trap the dirt. In winter in Seattle no such problem existed, for the jars regularly had to be bailed out. Freezing also caused some trouble, but addition of alcohol solved this to some extent providing the jars were picked up monthly instead of quarterly. Growth of algae was retarded, when necessary, by the addition of a fungicide.

At the end of a three-month period the settled dust in the water from each jar was evaporated to dryness and weighed. Distilled water was added to the dust and then the material was filtered. The residue was dried and weighed, thus giving the water insolubles. These insolubles were ignited and the ashes weighed to yield the total water insoluble ash. Aliquots of the filtrate were used for determining sulphates, chlorides, total water solubles, and the water-soluble ash. These results were then converted to tons per square mile per month for each station.

**TABLE I**
**AVERAGE DUST-FALL FOR FOUR MAJOR CITIES**

| City | Year | Average Total Solids (tons/square mile/mo) |
|---|---|---|
| Chicago | 1947 | 49.0 |
| Detroit | 1946 | 48.8 |
| Cincinnati | 1946 | 27.2 |
| Los Angeles | 1948 | 26.1 |

Table I shows the results of dust-fall tests for four cities. Individual readings as high as 175 tons per square mile per month have been recorded in other industrial cities before smoke abatement programs were put into effect. Where Seattle, with no smoke control, stands in comparison with other cities, is now being determined by the Laboratory.

The question has often arisen as to whether responsibility for urban air pollution rests more heavily on residential heating or on industrial processes. If the average dust-fall readings for the winter months are not substantially greater or are even less than the summer months, it will be apparent that residential heating is not a major contributor of larger particulate matter. With the predominance of oil-firing in Seattle, little difference in the average dust-fall for the various seasons is expected.

Dust-fall jars do not take into account the very small air-borne particle that does not settle. For this reason and others, after considering all of the variables outlined in the dust-fall jar procedure, four sampling stations for continuous air sampling were established. Three of these are in industrial areas; the fourth is on the University of Washington campus.

Continuous air sampling was accomplished by drawing one cubic foot of air per minute through a paper filter which was changed daily. Reflectance readings of the dirt collected on the filters were taken by means of a photometric unit that records the percentage of discoloration from the original white. Also, these filters were arranged in the order of a calendar and were photographed. Figures 1, 2, and 3 illustrate the difference in seasonal characteristics in an industrial area. Careful studies of the reflectance readings correlated with temperature, winds, seasons of the year, rainfall, barometers, etc., have shown highly inconsistent results. However, the correlation of inversions (temperatures near the ground lower than at higher altitudes) with the reflectance readings has been more nearly consistent than any other, thus indicating that the amount of air-borne dirt is a meteorological factor. Detailed study of these relationships are being made by Kenneth Olsen, a graduate student member of the staff, and will be released at a later date.

After a glance at the filters shown in Figs. 1 to 3, one might easily decide that the nearly black filters

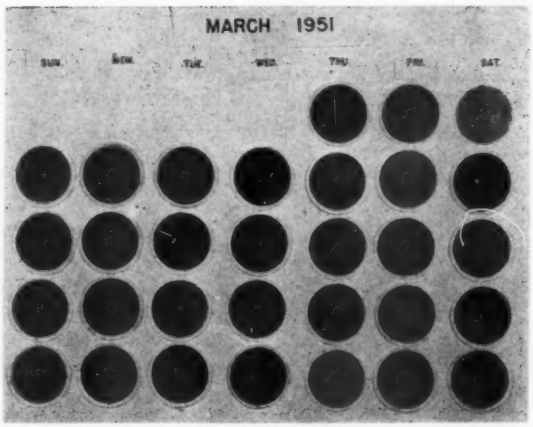


FIG. 1

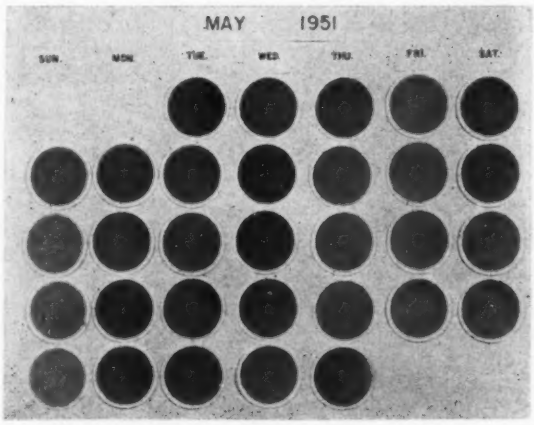


FIG. 2

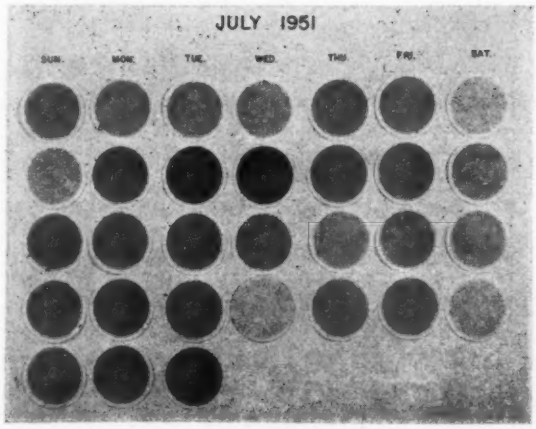


FIG. 3

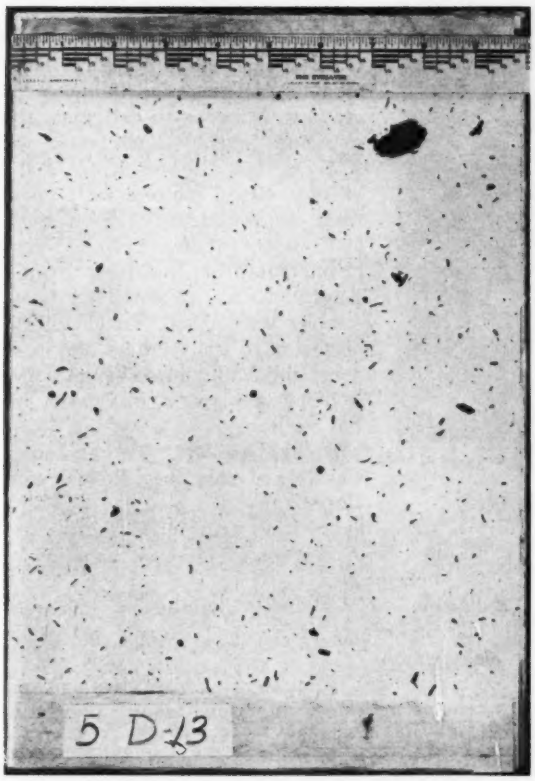


FIG. 4. TWO-HOUR SAMPLE OF HEAVY CINDER-FALL

obtained for the Sundays in March are a result of heating. However, a check of the inversions present during March indicated that the low-hanging fog prevented dispersion of the pollutants picked up during the week. Similarly, during the last of July several inversions with resulting haze were present. Generally in the summer months the meteorological conditions are not as stable as in the winter. Consequently, as shown by the filters illustrated, dispersal rate is greater in summer than winter.

Smoke and dust in the air reduce the amount of sunlight by scattering a part of the rays and by absorbing other parts. In Seattle's latitude the sun is comparatively low on the horizon, and hence comparatively less energy is received from the sun. Also, the general cloudiness in the Seattle area tends to reduce further the beneficial effects of the sun. Impurities in the air tend to cut off a specifically important part of the sunlight, the ultraviolet portion. Loss of the ultraviolet rays tends to reduce bodily vitality and thus decrease resistance to colds and other acute infections.

In order to determine the loss of the sun's energy in Seattle, a compilation of data from pyrheliometers at the Seattle-Tacoma Airport and at the University of Washington is being prepared. If the readings of the pyrheliometers, which record the sun's energy received in gram-calories per square centimeter per day, are materially less in Seattle than at the Seattle-Tacoma Airport, they should indicate the loss of available energy from the sun. The slight difference in latitude will cause a negligible error in these readings, while the effect of clouds should be minimized over a period of a year. Actually, the airport is not a perfect standard of available energy from the sun. Charles Chester, Director of the Washington Aeronautics Commission, who has cooperated in these studies, reports that clouds of smog have often been observed over that area.

Premature news releases have indicated a loss of 20 per cent in the available sun's energy due to the smoke pall over Seattle. However, this figure is not yet substantiated by the Laboratory.

None of the above techniques considers the presence of noxious gases. With the advent of many new industries in Seattle the question arises as to whether excessive amounts of fluorides exist in the air. Exhaustive tests are being made by Roy A. Veldee, a graduate student in civil engineering under the supervision of Mario Storlazzi, the Laboratory's industrial hygiene chemist. Lack of known fluoride-emitting industries would indicate that the extent of fluoride contamination is negligible.

Also extensive sampling was done for sulphur dioxide. With the exception of areas having extremely heavy traffic, $SO_2$ readings have been negligible. Currently, tests are being made for sulphur dioxide, carbon monoxide, and lead, during peak traffic hours in the downtown districts. The results of these tests will be released later.

Many other spot tests have been made on specific local conditions that cannot be covered in this report.

Another interesting grant involving the excessive fall-out of cinders in the Ballard area of Seattle is currently being conducted. A group of merchants contend that the cinders damage their displays. Each mill operator feels that *his* mill is not directly responsible. Cooperatively they have asked the Laboratory to study the situation and present the results.

In controlled tests involving wind direction, wind velocities, extent of mill operations, etc., two-hour samples of cinders are collected at stations surrounding the mill being studied. These cinders are collected on a poster with a sticky surface something like fly paper, and are photographed. Also, in order to determine the extent of the area over which mills spread their cinders, a fan-like arrangement of posters is placed downwind from the mill. In this way the effect of stack heights may be studied. Figure 4 shows a heavy fall.

FIG. 5. DR. J. LEON SEALEY IN LABORATORY TRUCK TAKES BLOOD SAMPLES FROM PILOT AND MECHANIC

**Occupational Health**

In the early nineteen-hundreds, with the advent of the gasoline-powered automobile, many people were injured or even killed because of general ignorance of the effects of gasoline exhaust gases on human beings. Today, with the development of rocket-fired airplanes, this same lack of knowledge exists concerning rocket exhaust gases. Consequently the Laboratory has received a grant from the U. S. Air Force to determine how man can live safely with this new condition. Since this project comes under security regulations it cannot be discussed at this time.

Another major grant was received from the American Cyanamide Company to study the effects of Parathion, an organic phosphate insecticide, on people in the areas which were sprayed or dusted with this preparation. In order to insure a completely objective study of this problem the company made an outright grant and did not limit the scope of the study. The Laboratory was also authorized to publish directly all results, regardless of what they might reveal.

In the apple growing areas of the state varied reports were being received of illnesses and even deaths occurring either during the time of or shortly after use of the new organic phosphates as insecticides. The Laboratory's job was to determine if safe practices were being followed in the use of the material.

Naturally, under the circumstances, the residents of the areas tended to be panicky. An investigation by the Laboratory unless carefully handled could have caused a wave of hysteria in the communities involved. In the face of this tense situation the staff under the direction of Dr. J. Leon Sealey began their investigation.

Air sampling for Parathion was carried out in conjunction with aircraft dusting, speed spraying, hand spraying, fogging, and thinning operations, in order to determine the exposure levels of not only the workers, but also residents of the vicinity. Blood samples were taken from approximately 175 workers and residents at an average of weekly intervals from mid-June to mid-August. In all, almost 2,000 blood samples were taken. To obtain cooperation of the workers and residents in donating blood samples was in itself a major achievement for Dr. Sealey.

From these tests the Laboratory was able to make the following conclusions:

1. All actual illness from organic phosphates has resulted from careless or ignorant handling of these chemicals.
2. Plasma cholinesterase determinations are reliable indicators of minimal organic phosphate absorption.
3. Erythrocyte cholinesterase determinations are reliable indicators of serious organic phosphate absorption and acute intoxication.
4. Most persons reporting "spray illnesses" to their family physicians have had no significant lowering of plasma cholinesterase.

These general conclusions drawn from the Parathion investigation have been briefed from the final report which was almost 100 pages long.

Another authorized study involves reported dermatitis among packers and sorters of apples where a fungicide is used to prevent mold. Currently nearly 100 volunteer women are undergoing patch tests to determine whether the fungicides used are primary irritants.

In addition, several smaller projects involving spot tests of dusts and toxic gases have been conducted in order to solve hygiene problems.

Currently, projects involving continued insecticide studies, handling of rocket fuels for the navy, precautions in the use of ozone, dermatitis in the fishing industry, and health hazards involved in industrial use of olivine are pending.

The Environmental Research Committee is composed of F. B. Farquharson, Director of the Experiment Station, (chairman); Dr. Harold E. Stoke, Dean of the Graduate School; Dr. Leland E. Powers, Executive Officer of the Department of Public Health and Preventive Medicine; Dr. Phil E. Church, Executive Officer of the Department of

Meteorology and Climatology; R. G. Tyler, Professor of Sanitary Engineering; A. W. Green, Assistant Professor in Public Health and Preventive Medicine; and Ernest M. Conrad, Assistant Comptroller of the University.

The Laboratory staff includes Dr. J. Leon Sealey, Medical Supervisor; Mario Storlazzi, industrial hygiene chemist; Arthur S. Gorai, industrial hygiene engineer, Vaughn Ransom, pharmacologist, Tom Hill and Robert Baughman, graduate student meteorologists; Pierre Jacquemin, engineering graduate student photographer; Warren Montgomery, Douglas Scholen, Kenneth Olsen, and Roy Veldee, Engineering Experiment Station research fellows; James Ritchie, machinist; and Alma Joslin, secretary.

Amazingly, although no state tax money is available to the Laboratory, it is finishing the year financially "on board." In addition, without cost to the University, 12 graduate students have received valuable research experience. Of these, three have completed their master's thesis requirements on subjects allied with their work.

The Environmental Research Laboratory, on the basis of this last year's activities, is confident that its kaleidoscopic research projects will contribute increasingly to the knowledge of environmental pollution effects and hence to the welfare of the people of Washington and other areas.

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# Resin-Sand Molding Process Developed on Campus

G. M. Schaller, Professor of Mechanical Engineering, and W. A. Snyder, Assistant Professor in the same department, after several years' research, have developed an original process of the "shell" type for using resin-sand for foundry molding. The following general description of this type of process is reprinted from the *Industrial Bulletin* of Arthur D. Little, Inc., No. 269:

"Both foundry men and makers of phenolic resins are working to bring a new resin-sand process for making foundry molds and cores to full-scale production, where it might well become the biggest single market for the resins. The automotive industry, as one of the chief users of small cast-metal parts, has invested more than two million dollars to investigate the process, and some pilot-line installations are now operating. Developed in Germany, and brought here after the war, the new process—variously called the 'Croning,' 'C,' or 'shell' process—promises real savings and improvements over conventional sand molding of cast iron and other metals. . . .

"Although there are many modifications of the new process, a typical example uses a mixture of 100 parts of dry sand and 8 parts of a thermosetting phenolic resin binder. A metal pattern is treated with a silicone resin, much in the manner of greasing a cake pan, and is then heated; the resin-sand mixture is dumped on the hot pattern, where it builds up to a thickness of ⅛ of an inch. The excess resin-sand mixture is shaken off and used again. The pattern covered with a thin layer of the resin-sand mixture about 3/16 inch thick is heated in an oven for one to four minutes until the resin is set, forming a thin shell over the pattern; the shell or "half-mold" is then removed from the pattern. Cores to fill hollow spaces in the final product are made by blowing the resin-sand mixture with compressed air into a split heated metal core box. Two of the half-molds, together with cores, if required, are assembled to make the completed mold. This is embedded in a box of steel shot, where it can receive the molten metal. The shot supports the shell and serves to control the heat of the molten metal; the resin-sand shell is sufficiently porous to allow escape of the gases, and no special vent is needed. This means an important saving in later finishing and machining costs, as well as savings in metal. The mold surfaces are so smooth that the resulting casting has excellent surface qualities, and requires little or no surface cleaning. Although each mold is good for only one casting, the metal patterns and the steel shot can be used indefinitely.

"It is claimed that sections as thin as 0.010 inch can be poured and, with care, tolerances of 0.002 to 0.003 inch for small castings can be achieved, thus lowering machining costs and saving metal. The method has been used successfully for castings up to 100 pounds, and it is expected to be most useful for mass production of identical and relatively small castings for automobiles, tractors, and farm machinery. Such items as door handles and exhaust valves are commonly cast, and savings in this operation could be substantial.

"The volume of sand necessary for making molds can be reduced by 90 per cent; machining and cleaning costs are claimed to be cut by as much as 80 per cent; improved working conditions result from the relative freedom from excessive dust and heat; more efficient handling of materials and better use of foundry floor space are also claimed. Hardened molds can be made ahead of time and stored until needed."

# THE UWAC—WASHINGTON'S ANALOG COMPUTER

ROBERT VON TOBEL
*Research Fellow, Engineering Experiment Station*

T. M. STOUT
*Instructor in Electrical Engineering*

R. von Tobel

As science advances, it seems that all the simple problems have been solved and that only difficult problems remain. At least scientists are encountering more and more problems whose solutions would require many more man-hours of tedious computation than can economically be spent on them. For this reason large high-speed computing machines are assuming increasing importance as a tool for scientific work and many such machines have been built in the last few years.

The University of Washington, through the Engineering Experiment Station, has sponsored the construction of a small electronic analog computer as an instrument for teaching and research. The computer, housed in the electrical engineering building and available for general use, is described in this article.

**Computer Types**

Computers for numerical work are of two general types, digital and analog. A digital computer, of which the abacus and adding machine are familiar examples, deals directly with numbers and uses counting devices of various kinds to perform addition and subtraction. By well-known principles, a digital computer can be instructed or "programmed" to perform multiplication or division, to extract roots, or to carry out other routine operations. More complicated operations, such as solving differential equations, are handled by splitting them into a sequence of simpler operations.

The accuracy* of a digital computer depends on the proper design and performance of its parts, and the approximations involved in the computing procedure which is employed. Its precision,* however, is limited only by the size of the machine, measured by the number of significant figures used. Application of digital computers is limited by the high cost of even a small machine and the large amount of time spent in program preparation compared to the time required for a single machine solution. The result is that digital computers are used primarily for repetitive calculations, such as compiling tables, in which a single program can be applied to a succession of different numbers. An important disadvantage to the engineer is the difficulty of changing problem parameters in order to observe, for example, the effect of a design change in some physical system.

T. M. Stout

In an analog computer, numbers are represented by measurable physical quantities, such as shaft rotations or voltages. The analog computer is, in a sense, a model of the problem to be solved and is programmed by interconnecting basic units, such as summing or integrating units, to correspond to the equations of the problem.

The precision of the results obtained with an analog computer is restricted by inability to read a meter or recording device to more than three significant figures. The accuracy depends on the calibration of the various units and the care exercised in their use. Analog computers are easy to use and cheap to build, and are therefore becoming common in industrial and research organizations. Because of the ease with which problem parameters can be varied and the entire connections of the computer changed, analog computers are very useful in design studies where the engineer wishes to examine rapidly the behavior of a large number of possible systems.

The UWAC, or University of Washington Analog Computer, is an electronic analog computer in which voltages represent the dependent variables, and time is the independent variable. Summation, multiplication by constants, and integration are done electrically by feedback amplifiers. The capacity of the computer is determined by the nature of the problem

* The term "accuracy" denotes conformity to truth, while "precision" signifies sharpness of definition: thus 0.33 is an accurate representation of the fraction one-third, but 0.3333 is more precise.

and the number of amplifiers available. Under favorable conditions as many as twenty simultaneous algebraic equations could be solved with the twenty amplifiers now available; at worst, the capacity is reduced to about ten equations. A similar capacity for solving linear differential equations may be extended in some cases by various special procedures.

Although the circuits and techniques employed in this computer are fairly standard, special attention has been given to arranging the various units for maximum operating convenience. The computer, shown in Fig. 1, is mounted in a three-section rack with the associated power supplies. The amplifiers are arranged in banks of ten on either side, with terminals for interconnection in vertical columns. Selector switches connect any of the amplifiers to the metering panel at the bottom of the center rack for balancing, measuring the output voltage on one of the voltmeters, or displaying the solution on the oscilloscope. A low-frequency sine- and square-wave oscillator, used to supply forcing functions, is also mounted in the center rack, together with various auxiliary units.

**Operational Amplifiers**

The operational amplifiers are high-gain, direct-coupled amplifiers using three dual triodes in a circuit which is designed to minimize zero drift problems. The first stage is a phase inverter and amplifier which transforms the single-ended input signal into a push-pull signal for application to the second tube. The second stage gives the extremely high gain of the unit through the use of positive feedback around both halves of the balanced stage. The last stage is a cathode follower used to reduce the output impedance to a low value. Over-all stability is obtained by negative feedback around the three stages. Because of the circuit arrangement, each amplifier produces a change of polarity or phase between input and output.

Operation of the amplifier as a summing unit is readily explained with the aid of Fig. 2. Although only two inputs are indicated, each amplifier is provided with terminals and resistors for five inputs. Since point $G$ is connected directly to the grid of the first tube, the current drawn by the amplifier is negligible, and the current equation at this point is, therefore,

$$\frac{e_1-e_g}{R_1}+\frac{e_2-e_g}{R_2}=\frac{e_g-e_o}{R_f}. \qquad (1)$$

Defining the amplifier gain by the relation $e_o=Ae_g$, the equation can be rewritten to eliminate $e_g$, giving

$$\frac{R_f}{R_1}e_1+\frac{R_f}{R_2}e_2=-e_o+\frac{e_o}{A}\left[1+\frac{R_f}{R_1}+\frac{R_f}{R_2}\right]. \qquad (2)$$

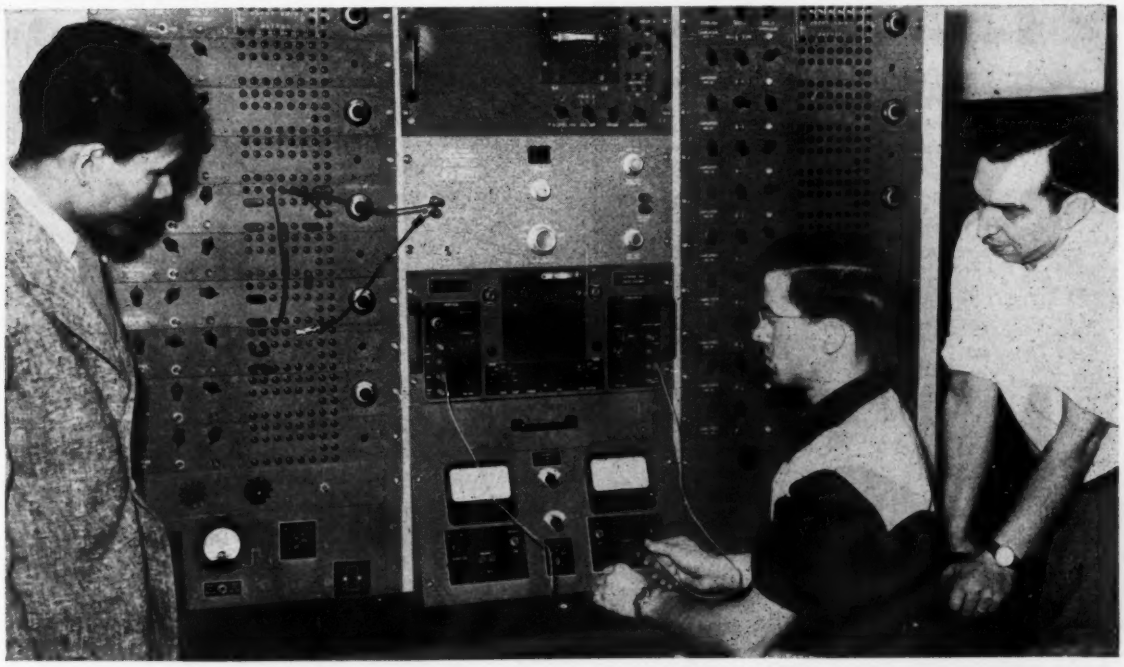

FIG. 1. UNIVERSITY OF WASHINGTON ANALOG COMPUTER
*Left to right:* **Chinubhai Shah and Melvin Eklund, research fellows, George Meacham, technician**

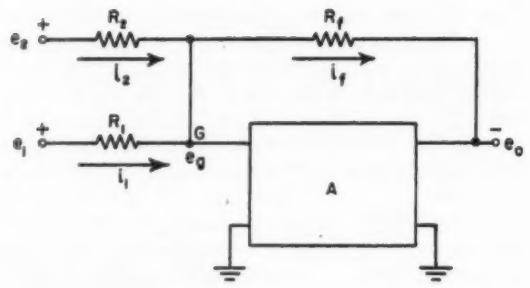


FIG. 2. OPERATIONAL AMPLIFIER USED FOR SUMMING

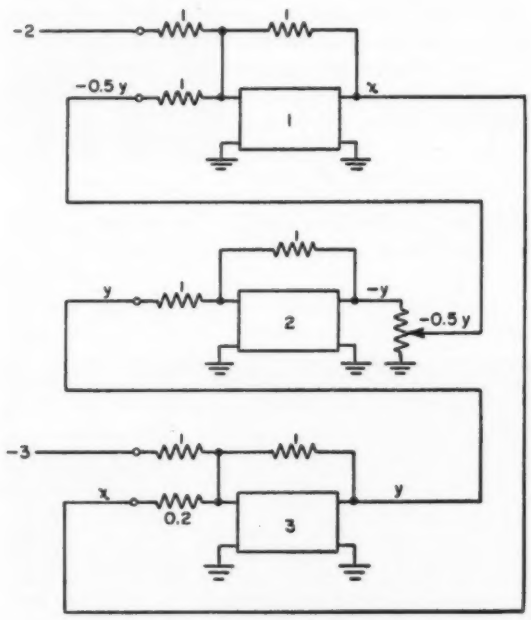


FIG. 3. OPERATIONAL AMPLIFIER CONNECTION FOR SOLVING TWO SIMULTANEOUS ALGEBRAIC EQUATIONS

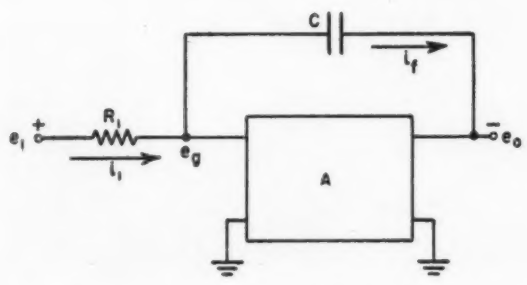


FIG. 4. OPERATIONAL AMPLIFIER USED FOR INTEGRATING

Ordinarily the resistors are approximately the same size. If $A$ is large (10,000 or so), the second term on the right side of Eq (2) is negligible and, very closely,

$$e_o = -\left[\frac{R_f}{R_1}e_1 + \frac{R_f}{R_2}e_2\right]. \tag{3}$$

Variations in $A$ are unimportant, so long as it remains large; the accuracy of the summation depends on the accuracy of the resistances. Resistors can be chosen to multiply each of the input voltages by a different constant. With a single input and $R_1 = R_f$, the amplifier functions as a sign changer.

### Algebraic Equations

Connection of the amplifiers to solve a problem in simultaneous linear algebraic equations is shown in Fig. 3. The equations are

$$\begin{aligned} 2x - y &= 4 \\ 5x + y &= 3\,. \end{aligned} \tag{4}$$

To adapt the equations to the computer, the equations are rewritten to conform with Eq (3) above:

$$\begin{aligned} x &= -(-0.5y - 2) \\ y &= -(5x - 3)\,. \end{aligned} \tag{5}$$

Three amplifiers are required, one for each equation and one as a sign changer. Coefficients are inserted by making the input resistor of the bottom amplifier one-fifth of the feedback resistor, to produce $5x$, and by use of a potentiometer across the output of the middle amplifier to give $0.5(-y)$. Constant inputs are provided by batteries, adjusted to the proper values by potentiometers.

The values of $x$ and $y$ which satisfy this pair of equations are then read with a voltmeter at the outputs of the first and third amplifiers. If volts represent numbers directly and no scale factors are used, the output of the top amplifier will be one volt and the bottom amplifier $-2$ volts.

### Integrators

The operational amplifiers may be used as integrators if the feedback resistor is replaced by a capacitor, as shown in Fig. 4. For simplicity, only one input is shown; in general the output is the integral of the sum of all the inputs, each applied through a separate resistor.

Circuit operation is easily visualized if $e_1$ is a constant and $A$ is assumed to be sufficiently large that $e_g$ is essentially zero. In this case a constant current, $i_1 = e_1/R_1$, is established which flows into the capacitor. The response of a capacitor to a constant charging current is a linearly increasing voltage.

Taking polarities into account, the output is thus the negative integral of the input. (Actually the output voltage must be less than 40 to 50 volts for satisfactory operation of the amplifiers; neon lights are used to indicate when this limit has been exceeded.)

In the general case, the current equation is

$$\frac{e_1}{R_1} = -C\frac{de_o}{dt}, \tag{6}$$

or

$$e_1 = -R_1C\frac{de_o}{dt}. \tag{7}$$

Integrating and rearranging,

$$e_o = -\frac{1}{R_1C}\int e_1 dt. \tag{8}$$

Integration constants can be included by putting an initial voltage across the integrating capacitors.

One-tenth microfarad polystyrene capacitors are built into each amplifier and connected to terminals on the amplifier panel. Larger and smaller capacitors can be connected externally as another method of handling numerical coefficients.

It is also possible to differentiate by interchanging the resistor and capacitor. This operation is to be avoided, however, since differentiation tends to accentuate noise or other extraneous voltages present in the input. Fortunately, the differential equations can be arranged so that only integration is required, so this is no handicap.

### Differential Equations

As an example of the use of integrating amplifiers, the solution of the well-known second-order differential equation,

$$m\frac{d^2x}{dt^2} + f\frac{dx}{dt} + kx = f(t), \tag{9}$$

will be considered. This equation describes, among other things, the motion of a mass suspended on a spring and subject to a frictional force proportional to its velocity and an arbitrary force $f(t)$.

To prepare the problem for the computer, it may first be written as two first-order equations:

$$m\frac{dv}{dt} + fv + kx = f(t), \tag{10}$$

$$v = \frac{dx}{dt}. \tag{11}$$

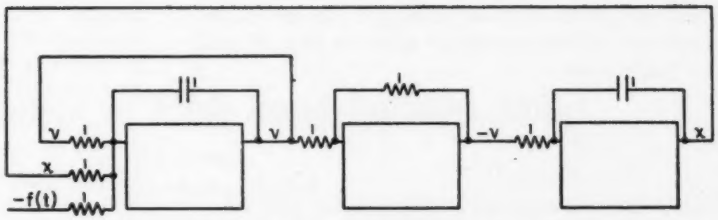


FIG. 5. AMPLIFIERS CONNECTED TO SOLVE SECOND-ORDER DIFFERENTIAL EQUATION

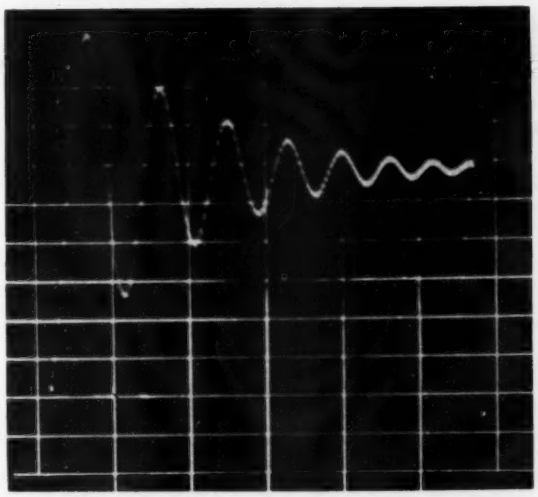

FIG. 6. DISPLACEMENT-TIME PLOT OF RESPONSE OF SPRING-MASS SYSTEM TO SUDDEN FORCE CHANGE
(Damping approximately one-tenth critical.)

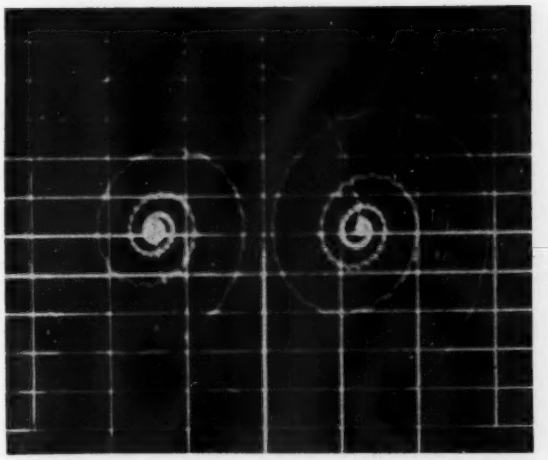

FIG. 7. VELOCITY-DISPLACEMENT PLOT OF RESPONSE OF SPRING-MASS SYSTEM TO SQUARE-WAVE FORCE CHANGES

These equations are then rearranged to fit the requirements of the computer given in Eqs (3) and (8), and become

$$v = -\int\left[\frac{f}{m}v + \frac{k}{m}x - \frac{1}{m}f(t)\right]dt\,, \qquad (12)$$

$$x = -\int(-v)dt\,.$$

One integrating amplifier is required for each equation and, in addition, a sign changer is needed to multiply the output of the first integrating amplifier by —1 to produce the input to the second. The computer connections, determined directly from the equations, are indicated in Fig. 5. For convenience, $m$, $f$, and $k$ have all been given unit values; other values are accommodated by adjustment of the feedback capacitators, input or feedback resistors, or by potentiometers across the outputs.

Two photographs of actual solutions of this equation are presented in Figs. 6 and 7. In both cases a square-wave input has been applied to an underdamped system, producing the oscillatory responses observed. The variation of displacement with time is shown in Fig. 6, while Fig. 7 is a plot of velocity as a function of displacement.

For best results, the output of any of the amplifiers should be big enough to be easily measured and yet small enough to stay within the range of linear operation. In some problems, however, the equations may demand that one output be very large while another is quite small. In such cases the variables of the problem can be transformed into new "computer variables" by a scaling process.

Simultaneous differential equations, or combinations of algebraic and differential equations, are handled by obvious extensions of the techniques already described. With the addition of units for simulating such nonlinear effects as saturation or backlash, the electronic analog computer becomes a versatile instrument for the solution of engineering problems.

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# To Readers of THE TREND

**Inquiry-reply postcards were recently sent out to 2,600 of the 4,300 names on the mailing list of *The Trend*. (Libraries and most academic personnel were not included.) The object of the query was to ascertain if any copies of *The Trend* could be painlessly directed elsewhere, in view of the rapidly increasing number of new requests for the magazine and a decreased operating fund. Replies from more than 1,300 of these readers have been received to date, over 90 per cent of whom indicated that they wished to be retained on the list. An entirely unanticipated "bonus" of good-will was collected from a gratifyingly large majority of the replies, many correspondents taking time and effort to voice their appreciation of our quarterly.**

**All names for whom signed replies have not been received up to March 25 will be dropped from the April mailing list. (Eight *unsigned* requests to be retained on the list have turned up so far!) However, a future request for reinstatement from any former reader will be honored, and back issues, if available, will be sent on request. Names of engineers on Washington membership lists recently received from the ASCE, AIChE, AIEE, and ASME, who have *not* been on our mailing list heretofore, are being added to the April list. These new readers are requested to let us know if they are not interested in continuing to receive *The Trend*.**

**The notices received included several hundred changes of address. Every effort will be made to follow these directives, but if mistakes occur we shall appreciate a card of correction.**

**Beginning with the July issue, *The Trend* will suffer a "face-lowering" as a result of a blow at its appearance. In view of economies which must be effected, the color and cut on the cover seem the logical place to start. We hope that the contents will continue to justify the interest of our readers and to fulfill the purpose of the publication. *The Editor*.**

# Record Attendance at Fifth Road-Builders Meet

R. G. HENNES
*Professor of Civil Engineering*

R. G. Hennes

The Fifth Northwest Conference on Road Building brought more than 350 engineers, industrialists and public officials to More Hall on February 13, 14, and 15. It was the most successful conference of its kind to be held in this region. Among those attending were 24 from Oregon, 12 from British Columbia, four from California, and two each from Idaho, New York and Washington, D. C.

The distribution of interest among the group provided a fair cross section of the road-building industry. Expressed in percent, the affiliation of the registrants was as follows:

23% were county engineers
22% came from state highway departments
18% came from industry
10% were city engineers
7% were contractors
7% were in engineering education
5% were legislators or commissioners
4% were federal engineers
4% were private engineering consultants

In opening the Conference, the Washington Director of Highways, W. A. Bugge, emphasized the growing regional importance of this annual meeting. After Dean Wessman had extended his welcome on behalf of the University, the remainder of the first session was devoted to a forum on bridge and traffic paint. Dan Jarvie, president of the Seattle Paint Club, described paint manufacturing processes. Two members of the Washington Highway Department, L. W. Cody and M. A. Lindeblom, described paint behavior under laboratory testing and its service record under field conditions.

The second session was held under the chairmanship of Rodney P. Ryker, Seattle District Engineer for the Asphalt Institute. Idaho State Highway Engineer Earl V. Miller described the test road being constructed for the western states to explore the effect of base thickness on pavement stability under four specified axle loads. The double oval includes four similar test sections, each of which will include the same various combinations of base and surfacing. The contract for this project has been let, and the sponsors expect testing to start in late summer, 1952, and to be completed in spring, 1953. Estimated cost of the program exceeds $300,000. George R. Egan, of the Western Highway Institute, suggested that a vital point of the project will be the collection of data on construction and maintenance costs corresponding to various axle loadings, which should be helpful in determining each highway user's proportionate share of highway costs. W. C. Williams, Assistant State Highway Engineer for Oregon, felt that the data would also be helpful to legislative bodies in setting reasonable maximum vehicle weight limits. An automotive engineer, Joseph K. Testu, of Kenworth Motor Truck Corporation, described the design problems imposed on the manufacturer by arbitrary length and weight limits. The test road should lead to more uniform standards throughout the western states.

The New Jersey turnpike was described by Walter F. Winters, Chief Engineer of the Asphalt Institute. This $255,000,000 highway, 118 miles long, included some unusual construction problems which were beautifully presented in a color film taken by the speaker.

The third technical session met Thursday morning under the chairmanship of Professor Martin P. Coopey, Oregon State College. Professor R. H. Meese, University of Washington, reviewed methods for reducing flood damage to roads. He suggested specifications for revetment exposed to various current velocities. A notable contribution to the conference was the paper by Professor B. R. Bertramson, in charge of agronomy at the State College of Washington. In addition to describing the value of turf in the control of bank erosion, he told of new chemical stabilizers, and of the Purdue research in growing turf on stabilized gravel shoulders without serious loss in bearing capacity.

Washington highway experience in compacting fills was correlated with laboratory research on compaction methods in the Materials Laboratory, by Lloyd Morgan, of Olympia. He described the devel-

opment of a kneading compactor which promises to become a standard test method because it produces a particle orientation similar to that obtained in the field by rolling.

The first American application of a new soil testing apparatus was reported by G. Bryce Bennett, Materials Engineer, Idaho Highway Department. The Swedish Vane Borer is being currently used in foundation studies for the Sandpoint bridge over Lake Pend Oreille, and is in many respects superior to more expensive laboratory procedures.

The chairman of the Thursday afternoon session was Bailey Tremper, who has consistently made valuable contribution to these road conferences since their inception. Mr. Tremper is resigning from his position as Materials Engineer with the Washington Highway Department to take up similar work in California.

A striking increase in the use of precast concrete bridges over Washington streams was described by Robert H. Lochow, field engineer with the Portland Cement Association.

Roy E. Jorgensen, of Washington, D. C., told of the need for more adequate roads. He said that the first step is the establishment of a sufficiency rating cut-off point, below which road sections are inadequate for proper service to motor transportation. Mr. Jorgensen has long been prominent in highway research. Formerly with the Connecticut Highway Department, he is now engineering counsel to the National Highway Users Conference.

Much interest was aroused by a discussion of floating bridges by the Chief Consulting Engineer of the Washington State Toll Bridge Authority, Charles E. Andrew. He pointed out some factors which govern the design of pontoons, including the effect of tides and wave action, and described the salient features of proposed crossings of Puget Sound.

Another timely problem was analyzed from various angles during the Friday morning session under the chairmanship of Mrs. Julia Butler Hansen, who is also Chairman of the Washington Legislative Interim Committee on Highways, Bridges and Streets. Mrs. Hansen explained the necessity for the establishment of a rational basis for highway classification which had led the legislature to undertake such an investigation. The study is being conducted for the Interim Committee, by the Washington State Council for Highway Research, at the State College and at the University of Washington. Minimum requirements for state highways were discussed by G. A. Riedesel, who heads highway research at the State College of Washington. An outstanding research development of this activity has been the establishment of a good correlation between inter-city traffic and the size and spacing of population centers, as described by Mrs. Willa W. Mylroie, Office Engineer for the Highway Classification Project at the University of Washington.

The use of this population factor in conjunction with factors measuring the state interest in highways which come from agricultural activity, trucking, bus travel, recreation, industry and commerce, was explained by the writer. Carl E. Fritts, Vice-President in charge of Engineering for the Automotive Safety Foundation, Washington, D. C., described the classification methods adopted by other states. Mr. Fritts will be remembered by his work on the 1948 report on the highway needs of Washington, of which the present classification project is an outgrowth, as well as for similar studies in many other states.

The closing session of the Conference was devoted to county road problems, and was held under the chairmanship of Richard Watts, executive secretary of the Washington Association of County Commissioners. William A. Stancer, Pierce County Engineer, said that maintenance consumes most of county road funds, and its cost can be reduced only by correction of subgrade deficiencies in the construction stage through the application of basic principles by qualified personnel.

Most highway traffic develops along patterns which were established in the early history of the state. A notable exception exists in the Columbia Basin project, where a marked alteration in the over-all economic picture is in progress. The development of a road program for Grant County, which holds more than usual interest because of this feature, was well covered in a paper by James H. Dodson, Grant County Engineer. The Conference closed with a panel discussion on uniform standards for county roads. H. O. Walberg, Skagit County Road Engineer, treated this topic from the standpoint of legislative background and current engineering practice. Neil R. McKay, Assistant Director for State Aid, in the Washington Highway Department, explained that his division acts for the state in an over-all administrative and advisory capacity, with the county road departments participating to a degree in the setting of uniform design standards for county arterial highways with the authority to grant deviation permits for exceptions to the standards. The final speaker was B. J. McClarty, Secondary Roads Engineer for Division 8 of the Bureau of Public Roads. He reviewed some of the standards advocated by the Bureau of Public Roads for use in designing federal aid secondary projects. Their basic policy favors the construction of a secondary road which will serve the volume and character of traffic reasonably well in all types of weather, and which can be maintained at reasonable cost.

# SOME PROPERTIES OF TRIETHYLENE GLYCOL LIGNIN

PIOTR ZENCZAK, D. F.
*Assistant Research Wood Technologist, Engineering Experiment Station*

P. Zenczak

In the spring of 1949, research in the Forest Products Laboratory of the University of Washington, under a grant from the Engineering Experiment Station, resulted in the discovery that, under proper conditions of use, triethylene glycol will completely defibrate wood chips and dissolve lignin.[1] When the triethylene glycol extract is diluted with water, a reactive lignin is obtained as a precipitate.

Any lignocellulosic material such as wood chips, bark, or sawdust, is heated for one to four hours at 120-140° C with triethylene glycol containing 0.2-0.5 per cent of catalyst. Experiments at the Forest Products Laboratory have been carried out in an electrically heated stationary digester with a capacity of five gallons, under ordinary atmospheric pressure. The cellulosic residue is filtered from the cooking liquor and is washed with triethylene glycol and water. The lignin present in the cooking liquor is precipitated by the addition of one to two parts of water. In the case of seven per cent solution of lignin in triethylene glycol, one part of water precipitates about 80 per cent; two parts of water about 98 per cent of the lignin present in solution. The precipitated lignin complex is filtered, washed with water, and oven-dried at maximum 50° C. This general procedure of extraction of lignin by triethylene glycol must be modified, depending upon the type of lignocellulosic material that is extracted and the end-properties that are desired. In the case of pulp production, the characteristics and quantity of the catalyst are very important. Metal chlorides, e. g., aluminum chloride, hydrochloric acid, or hydrogen chloride, can be used. If pulp of maximum strength and high yield is desired, the hydrogen ion activity must be kept at a minimum and controlled by the use of a buffer solution.

Delignification is essentially a surface reaction. The reaction proceeds rapidly at first, and then slows down as the concentration of the solvent decreases and that of the solute increases in the immediate area of contact. For this reason, circulation of the extracting liquor is desirable, although completely satisfactory results were obtained without circulation.

**Recovery and Re-use of Triethylene Glycol**

The mother liquor, after the separation of the lignin, contains triethylene glycol, water, small amounts of nonprecipitated lignin complex, and minor amounts of water-soluble carbohydrates. Because of the difference in vapor pressure, and the relative volatility of water and triethylene glycol, water is easily distilled off, and the losses of triethylene glycol appear to be negligible. Concentrated glycol containing up to five per cent water, in some cases, was re-used as cooking liquor.

The stability of triethylene glycol is remarkable. No ester formation or other decomposition reactions were noticed. In some instances, triethylene glycol was re-used twenty times with good results. No accumulation of sugars or lignin degradation products was observed. This fact may be explained in the following way: the triethylene glycol lignin complex precipitates in the form of very fine colloidal particles of high sorption surface area, and therefore excess solubilized carbohydrates may be adsorbed on the surface of the freshly precipitated lignin. During purification of lignin precipitates, those adsorbed carbohydrates are washed away. Some volatile carbohydrate decomposition products are also removed when the triethylene glycol is concentrated.

**Extraction of Lignin with Other Glycols**

A total of thirty-one different glycols were investigated as possible substitutes for triethylene glycol.* The majority of those tested were completely unsuitable as lignin solvents because esters were formed even when only traces of acidic catalysts were present. Some have a decomposition point which is too low for the temperature required; others are only partly soluble in water, which, of course, makes recovery difficult and expensive. Ethylene glycol, which is relatively stable and water soluble, extracts only a part of the lignin.[2] This may be due to the

* Kindly provided by the Carbide and Carbon Chemical Corporation; the Dow Chemical Company; the Shell Chemical Corporation; and the Celanese Corporation.

orientation of the molecules at the solvent-lignin interface. The fact that the molecular structure of an alcohol has a profound effect on its ability to extract lignin was noticed during an investigation of monohydroxy aliphatic alchols as a solvent for lignin by Aronowsky and Gortner.[3]

Triethylene glycol contains two hydroxy and two ether groups evenly balanced. It is known that such balanced structure in polyglycols gives superior solvent properties.[4]

## Characteristics of Triethylene Glycol Lignin Extracted from Douglas Fir Wood Chips

### *Physical Properties*

Lignin precipitated from triethylene glycol lignin is diluted by pouring it into an excess of ice-cold water to form a colloidal solution. The size of primary, more or less spherical, particles is not uniform and varies from 100 Å to 1,000 Å in diameter. This colloidal solution will pass through ordinary filter paper and is stable at room temperature. It can be coagulated by the addition of electrolytes.

By adding water to an excess of triethylene glycol lignin solution, and by increasing the temperature, the precipitating primary particles of lignin form agglomerates sufficiently large to settle out under the influence of gravity. This type of precipitate is easily filtered or centrifuged as a light cream-colored paste. Precipitating temperatures over 90° C cause melting of the freshly-formed lignin so that it may be collected as a water-insoluble viscous tar.

In the dry state, triethylene glycol lignin is an amorphous powder. Its color varies from light cream or light gray to light brown, depending on the source and the method of its preparation. It has a melting point ranging from 100°C to 140° C. Water acts as a plasticizer, i. e., the melting point is lowered. The low melting point and light color are among the physical properties which distinguish triethylene glycol lignin from commercially available lignins, which are not thermoplastic, or which have sintering points of 210° or higher. The triethylene glycol lignin exhibits a desirable degree of solubility in a variety of solvents. It is completely soluble at room temperature in 95 per cent methyl or ethyl alcohol, as well as in acetone-water mixtures, and other strongly polar solvents. Good solubility in some substituted aromatic compounds and in heterocyclic and dicyclic compounds is also apparent. The solubility of this lignin in dilute (one to ten per cent) sodium hydroxide and sodium carbonate, and its insolubility in the bicarbonate indicate that it is phenolic in character. Triethylene glycol lignin is insoluble in 30 per cent sodium hydroxide and only partly soluble in 20 per cent sodium hydroxide. About 30 per cent of the crude triethylene glycol lignin is soluble at room temperature in chloroform. By fractional precipitation from triethylene glycol, a number of fractions have been prepared. These fractions differ in melting point, color, and solubility behavior. Circular chromatograms prepared from triethylene glycol lignin on filter paper resolved it into three different colored zones. This suggests that lignin is a multi-component complex. These zones, after separation, are currently being investigated. No changes in physical properties were apparent on aging of triethylene glycol lignin.

### *Chemical Properties*

The triethylene glycol lignin gives a very positive pink color phloroglucinol test; after treatment at reflux temperature with two per cent HCl, this phloroglucinol reaction is not shown. Numerous analyses have been carried out to determine the methoxyl content of different fractions of triethylene glycol lignin, using the Viebock and Schwappach method. Differences in the values were within one per cent of the methoxyl content of the purified total triethylene glycol lignin complex. The total triethylene glycol lignin complex extracted from Douglas fir wood contained 15.3 per cent methoxyl. After two hours hydrolysis with twelve per cent hydrochloric acid, the methoxyl content was reduced to 11.9 per cent. All attempts to hydrolyze the assumed glycol radical with 42 per cent hydrochloric acid to detect triethylene glycol in the hydrolyzate have been unsuccessful. This is surprising because it is known that methoxyl, for example, is easily split from methanol lignin. It is possible that the triethylene glycol does not enter the lignin molecule and that the isolation of lignin by extraction with triethylene glycol is a catalyzed solvolytic cleavage of a polymer in a very suitable solvent. It is of interest to mention that lignin is not extracted from wood by pure triethylene glycol even if the wood has been previously subjected to prolonged acid hydrolysis and then washed with water until it is substantially neutral.

The triethylene glycol lignin possesses the ability to flow and self-polymerize under the influence of heat at temperatures used in plywood hot presses. This property is very useful in preparation of wood glues from triethylene glycol lignin. In the hot press, a specific bond is formed between wood and triethylene glycol lignin whose strength is effected by hydrogen ion concentration. To obtain a maximum strength and water-resistance of the bond, pH of the glue must be adjusted and controlled. Its optimum varies depending on particle size of lignin, the form in which it is applied, and conditions of gluing. In testing this property, Douglas fir veneers were glued with triethylene glycol lignin under conditions similar to those used with hot-setting phenol-formalde-

hyde glues. The triethylene glycol lignin can be applied in the form of water dispersions, condensate colloidal water solution, or emulsion with ethyl or carboxylmethyl cellulose at desirable viscosities. Three-ply specimens of the conventional design used in shear testing of plywood were prepared and tested dry and after boiling. Both dry and boiled shear values and wood failures were equal to, or better than, values obtained with commercial phenol-formaldehyde glues. In some cases, dry shear values over 320 psi and wet values over 250 psi were recorded. These tests prove a possibility of the development of a superior, inexpensive, waterproof glue for plywood and a binder for hardboard. In the latter case, triethylene glycol lignin should be applied as a colloidal sol and precipitated by a suitable electrolyte on fibers. In this way, uniform coating of fibers is obtained, which is essential for securing optimum results.

Triethylene glycol lignin can be co-precipitated with rubber latex or proteins. Very intimate physical association is evident in electron microscope photographs (Fig. 1). By co-precipitation of triethylene glycol lignin with soybean protein, a soybean glue was prepared with improved water resistance and hot-set properties.

The triethylene glycol lignin reacts with furfural, phenol, aniline, and formaldehyde to form resins. Some of these resins form irreversible gels on heating or at room temperature, on addition of catalyst. On drying, gels are converted to hard water insoluble plastics with promising characteristics.

By use of triethylene glycol as a solvent for lignin, the modern technique of stepwise countercurrent solid-liquid extraction may be applied in the pulp industry. Such a new pulping process may not only help to solve the lignin problem, but will constitute a major improvement in yield and quality of pulp.

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2. Hibbert, H., and Rowley, J. H., *Can. J. of Research*, Vol. 2 (June, 1930), p. 358.
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4. Lawrie, J. W., *Glycerol and Glycols*, the Chemical Catalog Company, New York, 1928.

**Fig. 1. Lignin co-precipitated with rubber latex 1:1. Large latex particle is covered by smaller colloidal particles of lignin.**

**Palladium shadow 3:1 X 45,000**

# A RECORDING INTERFEROMETER FOR CALIBRATING STRAIN GAGES

ALBERT S. KOBAYASHI
*Research Fellow in the Engineering Experiment Station*

FIG. 1. THE UNIVERSITY OF WASHINGTON INTERFEROMETER
Mr. Kobayashi is observing the fringe order as indicated by the electronic counter

FOR THE PAST TWO DECADES, interferometers used for calibrating strain gages were of either the Michelson or Fabry-Perot type, in which a carriage mounted on a precisely machined bed was shifted by a micromotion screw, and the interference fringes were counted visually through a telescope. Under the supervision of Professor E. E. Day, the writer has designed and built a simply constructed Fabry-Perot interferometer which eliminates all of the precision machining and records the number of interference fringes automatically by an electronic counter. This counter, based on a commercial unit, was adapted and improved in design by the Electronic Group of the Engineering Experiment Station. The entire apparatus is mounted on a portable foundation that can be easily moved about.

## Interferometer Design

The reflected fringes of this Fabry-Perot interferometer can be observed visually, while the transmitted fringes are recorded by the counter. This design enables the fringes counted automatically to be under constant observation, and any change in the fringe shape or the location of the fringe center can be detected in order to avoid unexpected error which might be introduced in the calibration process.

From the theory of interferometry, the relative displacement of the two optical flats in air can be measured in terms of the parallel incident light wave length. This measured displacement is, in turn, used as the known quantity for calibration. The relation between displacement and light wave length is given

by:

$$d = m.\ \lambda/2,$$

where $m$ is the number of the fringes which pass through the observation point, $\lambda$ is the light wave length, and $d$ is the displacement. Thus, by counting the fringes, $d$ can be measured to an accuracy of one-half of a wave length.

The light source for this interferometer is a mercury-vapor lamp filtered by Wratten filters No. 58 and 77 to eliminate all but the 5461 Angstrom Unit component and thus gives an accuracy of $1.0749 \times 10^{-5}$ inches.

The stationary mounting for one 2-in. optical flat is suspended by means of three flat suspension springs arranged in an isosceles triangle. By means of the micromotion screws on the instrument frame, minute changes in position of these screws against the flat springs move the optical mount so that the flat can easily be set within one-quarter of a wave length.

The micromotion of the carriage for the other optical flat is guided by a pair of short elastic hinges which form a parallelogram giving a parallel, though not a perfect rectilinear, motion. This mounting can be seen in Fig. 1. In the design of the clamping arrangement special attention was paid to the elastic hinges in order to maintain equal mechanical conditions of the two hinges and thus eliminate any unbalance which might cause the carriage to warp or rotate during its movement.

Displacement between the two optical flats is obtained mechanically by utilizing the horizontal shearing action between two leaves of a leaf spring in bending. The bending is done by a rotating crank which is connected to a stepped-down synchronous motor. The total travel of the movable optical flat thus obtained is about 0.01 in. and return, in 24 minutes. This speed causes about one fringe shift every 0.6 second, so that the shifts may be counted visually if desired.

**Electronic Counter**

For an electronic counter, a Model 310 made by the Potter Instrument Company was used. The original photoelectric cell was replaced by a photomultiplier tube 931-A, and a single stage amplifier with a detector was inserted in order to increase the total gain of the count detector. The voltage level of the multiplier tube had to be carefully adjusted so that the fringe detector might be able to count the dim fringes that passed the observation point, but would not be so sensitive as to record stray pulsations such as the 60-cycle, or minute vibration of the interference fringes.

**Accuracy of Calibration**

Some error in this apparatus results from the nonrectilinear movement of the movable flat mounting during its travel. This error, estimated by observing the shift of the fringe center, was 0.22 per cent of the displacement of the two optical flats.

The electronic counter, which records each fringe shift but not the fractional change of a fringe, gives a calibration accuracy of $1.0749 \times 10^{-5}$ in. Fractional part of a fringe shift may be estimated to one-tenth of a fringe when observed through a telescope. This gives the displacement to an accuracy of one-twentieth of $\lambda$, or $1.0749 \times 10^{-6}$ in. for the mercury green line.

With adequate adapters, this recording interferometer can be used to calibrate many types of mechanical, optical, and electrical strain gages.

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# Notes and Comments

## ENGINEERS IN THE NEWS

A 600-word abstract of a paper, "Stability and Durability of Plant-Mix Macadam," by Professors **R. G. HENNES** and **J. R. CLANTON,** was published in the January 30, 1952, issue of the British weekly, *Highways and Bridges.* The paper, which was presented before the 31st meeting of the Highway Research Board, was based upon research performed under Engineering Experiment Station Project No. 6 on bituminous paving mixes. *Highways and Bridges* published only four other abstracts out of the 153 papers presented at the Washington D. C. meeting. Highway Research Board is a division of the National Research Council.

**MILNOR ROBERTS,** Dean of the University School of Mines 1901-1947, was admitted into the Legion of Honor of the American Institute of Mining and Metallurgical Engineers at the Institute's annual banquet in New York City. A gold pin and a certificate commemorating his 50 years' membership in the organization were presented to him.

**F. D. ROBBINS,** Assistant Professor of Electrical Engineering, has been invited to read a paper, "The Place of Coal-Burning Steam Plants in the North-

*(Continued on page 32)*

# A Wireless Lapel Microphone

LeRoy D. Barter
*Junior Research Engineer, Engineering Experiment Station*

In an ordinary public address system the speaker must talk into a relatively fixed microphone; even with a lapel microphone he must stay within the limits of the microphone cable. In certain instances, the elimination of the microphone cable would justify more complex equipment. For instance, a radio actor on a stage, a dance instructor on a dance floor, an interrogator in an auditorium, would like to move around without the restriction of trailing wires. To meet this need, the wireless lapel microphone was developed.

It is a very common phenomenon that energy can be transmitted by means of a transformer. The wireless lapel microphone uses this principle as shown in Fig. 1. The coil of the transmitter acts as the primary of a transformer, and the coil of the receiver acts as the secondary of the transformer. So long as the primary stays within the area of the secondary coil, the amount of the energy transmitted to the receiver will be practically constant. This has a distinct advantage over ordinary radio transmission where the energy transmitted varies inversely with the distance between the transmitter and the receiver.

The signals from the microphone modulate the 100-kc carrier of the transmitter. Both of the coils are tuned to the carrier frequency. The receiver then detects the signal which is amplified by a standard microphone public address system. Hence the lapel microphone, transmitter, and receiver, perform the function of the usual microphone, but with the advantage of no connecting wires between the speaker and amplifier.

In use, the transmitter and batteries are small enough to place in the speaker's pockets, while the primary coil is worn like a belt. (See Fig. 2.) The lapel microphone is either fastened on the lapel or placed in the breast pocket. The secondary coil is then strung around the auditorium or stage to include the area in which the speaker wants to move. In the case of a permanent installation, the secondary coil can be placed within the walls.

When more than one speaker or actor is concerned, the vocal volume of each one can be separately and conveniently controlled, if desired, by standard amplifying systems.

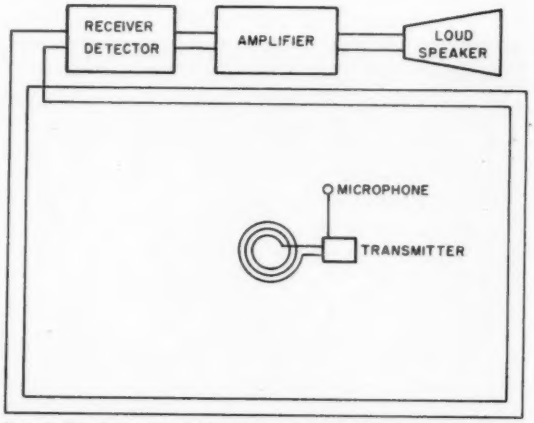


Fig. 1. Diagram of "Wireless" Lapel Microphone Setup

Fig. 2. Mr. Barter Wearing the Wireless Microphone Equipment

**With transmitter and batteries stowed in his pockets, and the wires around his waist concealed by his coat, only the lapel microphone is visible.**

# RESEARCH ON SWEPT WINGS

HAROLD C. MARTIN
*Associate Professor of Aeronautical Engineering*

H. C. Martin

Prior to World War II, the aeronautical engineer could consider aerodynamic design and structural design as independent components of the over-all aircraft design problem. This separation of effects was made possible by the comparative stiffness of the structure. In other words, the airplane could be treated as a rigid body, any interaction between structural deflections and aerodynamic forces being of negligible importance. The resulting simplification in design was enormous.

This relatively simple state of affairs was upset when flight speeds reached and exceeded the 400-500 mph bracket. At these speeds structural deflections were found to produce an appreciable influence on the aerodynamic characteristics of the airplane.

Recognition of the fact that the interrelation between structural stiffness and aerodynamic effects is crucial to the proper design of the high-performance airplane has led to a new field of aeronautical specialization, namely, aeroelasticity. This new field integrates the formerly distinct design branches of aerodynamics and structures. The net result is a tremendous complication in the problem of designing the airplane.

The thin, and often swept, wing of the modern high-speed airplane is probably the most important single structural component from an aeroelastic point of view. As such it has been the subject of much study during the past few years. The purpose here will be to point out one or two typical aeroelastic problems associated with the swept wing, and to review briefly some of the research in this field which has been carried out by the Department of Aeronautical Engineering at the University of Washington.

It is not difficult to understand the basic aeroelastic problem of the swept wing—or of any other structural unit of the airplane, for that matter. For a given flight condition the problem is basically that of determining the equilibrium state which must exist between external (aerodynamic) and internal (elastic) forces. Dynamic effects are omitted. For the swept wing this requires that the engineer be able (1) to solve the aerodynamic problem of the swept wing, (2) to solve the structural problem of the swept wing, (3) to solve for the equilibrium state, taking into account the fact that aerodynamic and elastic forces are mutually dependent.

As a typical example consider the steady level flight of the high-speed airplane. Since this is a possible flight condition, the design engineer must know the loading distribution over the wing in order to properly check such items as structural strength, stability characteristics, and so on. However, since the wing is assumed to deflect sufficiently to influence the aerodynamic forces acting over its surface, it is clear that the solution for the level flight equilibrium state is going to present some difficulties.

The problem of determining the equilibrium state for the swept wing is treated in "A Superposition Method for Calculating the Aeroelastic Behavior of Swept Wings," by Brown, Holtby, and Martin.[1] The approach to the swept wing aeroelastic problem as developed there had its origin in the Boeing Airplane Company where it was the writer's privilege to be associated with this work during summer employment at Boeing in 1949.

Although an adequate description of the Superposition Method cannot be given here, some of its general features may nevertheless be of interest. In the first place, the method was developed with the needs of the design engineer in mind; hence simplicity of method and applicability to design were stressed. The method is developed on the basis of the following initial information:

1. Wing-load distributions corresponding to certain selected angles of attack
2. Wing structural geometry and elastic properties

The above basic information can come from either experimental or theoretical sources. Once determined it forms the basis by means of which the Superposition Method may be established.

The Superposition Method possesses the following features of interest to the design engineer:

1. Mathematics is limited to simple algebra.
2. The method can be extended to give any degree of exactness considered necessary.
3. The method is not unduly time consuming and can be accomplished with a slide rule.
4. The engineer need not lose touch with the physical problem in carrying out the mathematics of the solution.
5. Once certain parameters have been determined for a given equilibrium state, the solution to a large number of design questions follows at once by a simple application of the superposition technique.
6. The method is quite flexible and lends itself well to adaptation to special cases, problems, and so on.

The component problem of determining aerodynamic characteristics of the swept wing is a difficult one. A vast amount of research has been devoted to this problem in recent years. Perhaps the most useful effort from the Department of Aeronautical Engineering in this field is the Master's thesis by H. A. Cole, Jr., "Determination of Rolling Characteristics of Flexible Wings with Sweepback by Matrix Methods." Although unpublished, the method developed by Cole was used to check some of the experimental work on swept wings reported in Reference 4. This work is concerned with the lateral control of the airplane and will be discussed later on.

The other component problem, namely that of calculating the structural deflections of the swept wing, also poses some difficult questions. From the design engineer's point of view it would be highly desirable if the swept wing could be treated in conventional manner; that is, if deflections could be determined from elementary beam and torsion theory. Whether the swept wing can be so considered *a priori*, is not known.

Since the *thin* wing of the high-speed airplane must support tremendous forces, the comparatively small cross-sectional area must be compensated for by a corresponding increase in the solidity of the internal structure. As a result the thin wing tends to approach the limiting case of the solid cantilever plate. This, plus the fact that the flat plate actually finds use in the form of fins on some missiles and rockets is responsible for the large amount of experimental and theoretical research which has been devoted to this subject during post-World War II years.

Experimental research on swept cantilever plates in the Department of Aeronautical Engineering has shown that elementary theory, if properly applied, may be used to calculate the deflection of such members. The key to this approach lies in the discovery that the plate may be replaced by a beam—provided this beam is properly located.

As is well known for the unswept plate, the equivalent beam must be placed at the elastic axis. Any loading whose center of pressure lies on this axis will then produce bending but no twisting of the plate. Furthermore, in the case of the unswept plate, the elastic axis is a function of the cross-sectional properties only (sections taken parallel to the clamped edge).

In "An Observation Regarding the Deflections of Uniform Swept Cantilever Plates," by Gursahaney and Martin,[2] it is shown that an "apparent" elastic axis exists for the swept plate which is analogous to that previously discussed for the unswept case. However, in this instance the location of the axis depends on the angle of sweep as well as on cross-sectional properties. This report compares experimental and calculated results for several uniform plates subjected to various kinds of loadings. It is shown that the use of the apparent elastic axis permits deflections to be calculated with satisfactory engineering accuracy.

Extension of this work to the more general case of the tapered plate (actually, triangular planforms) with sweepback is presented in the article, "On the Deflection of Swept Cantilevered Surfaces," by Martin and Gursahaney.[3] The experimental evidence presented shows that for the tapered swept plate, with at least moderately high aspect ratio, an elastic axis exists as in the case of the untapered plate. The plate can then be replaced by this axis, which is given a lengthwise distribution of bending and torsional stiffness dependent upon the sectional properties of the plate. Calculated deflections may then be readily carried out and are again shown to be in good agreement with experimental values. Location of the apparent elastic axis is determined experimentally.

More work needs to be done on this approach to the deflection problem of the swept cantilever. First, the apparent elastic axis should be investigated experimentally for the typical built-up type of wing structure. Second, if possible, a method for locating this axis from elementary structural theory should be developed.

At this point mention should also be made of the fact that some dynamic characteristics of the swept plate can be simply computed by using the apparent elastic axis. In Reference 3 it is shown, for example, that the first three natural frequencies in bending of the uniform swept plate are obtained with excellent accuracy on this basis.

The problem of controlling and manoeuvering the airplane in flight is also influenced by the aerolastic behavior of the wing. A typical example is that of producing roll, usually by deflecting the ailerons.

An airplane in level flight can be made to roll by increasing the lift on one wing, while decreasing that on the other. This is conventionally achieved by motion of the ailerons.

It has been known for decades that, when aileron deflection is used to increase the lift over a wing, the new distribution of loading will normally tend to twist the wing. Since aerodynamic forces increase with the square of the speed, this twisting tendency becomes greatly aggravated as the speed goes up. Furthermore the direction of the twist is invariably such as to counteract the effect produced by the aileron motion. As a result there will be a speed at which the rolling effect produced by aileron motion is exactly counteracted by the opposing effect due to wing twist. This is known as aileron reversal; when the speed exceeds the aileron reversal speed, motion of the ailerons will twist the wings to such an extent that the resultant rolling motion is just opposite to the usual direction. This phenomenon occurs on unswept and swept wings, and has been observed in the wind tunnel and in actual flight. The designer is most anxious to keep the aileron reversal speed well above the maximum speed at which the airplane will ever fly.

The problem of aileron reversal becomes complicated, for structural reasons, in the case of the swept wing. A wing with sweepback will suffer induced twisting if subjected to bending forces, and vice versa. In other words, bending induces twisting, and this fact influences the lateral control problem. For example, since the sense of the induced twist is such as to oppose the rolling effort produced by the aileron, both bending and twisting deflections of the swept wing must be examined for their effect on the lateral control of the aircraft. The unswept wing is simpler to handle since, there, bending does not induce twisting and hence does not affect the rolling moment produced by aileron action.

As might be anticipated, the problem of predicting the lateral motion of the airplane is not a simple one. In particular one would wish to compare calculated results with experimental data in order to check the validity of the theory; also, it would be helpful to observe the influence of various spanwise locations for the ailerons on the rolling performance of the wing. Studies of this problem were carried out for the National Advisory Committee for Aeronautics by the Department of Aeronautical Engineering. Results are given in "Experimental Investigation of Rolling Performance of Straight and Sweptback Flexible Wings with Various Ailerons," by Cole and Ganzer.[4]

The authors conducted tests on flexible wings with known structural properties in the University of Washington tunnel. A number of quantities of importance in the lateral control problem were measured and then compared with calculated results. Among the theoretical methods used was that of Cole, which has already been mentioned.

Some general conclusions reached in this report are as follows:

1. The swept wing had higher aileron reversal speeds than the comparable unswept wing.
2. The swept wing with ailerons placed inboard from the tip had higher aileron reversal speeds than the wing with ailerons mounted out at the tip.
3. Aileron reversal speeds for the unswept wing tended to be constant for any spanwise location of the ailerons.
4. Theory checked experimental data quite well for the unswept wing but did not always give satisfactory agreement with data obtained for the swept wing.

The research briefly discussed above applies to some of the problems of current interest to the airplane designer.

Since for any given structure, structural stiffness remains a constant while aerodynamic forces increase rapidly with speed, it is to be expected that fuselage and tail deflections will also exert an influence on the behavior of the aircraft in flight. A similar situation exists for the missile. Aerolasticity is concerned with the complete structure and embraces dynamic as well as static effects.

While the search for basic design information and methods has been going on, airplane manufacturers have gone ahead and built many successful aircraft of the type considered here. This has, however, been largely accomplished at the expense of an enormous amount of wind-tunnel testing on carefully built flexible models of the actual design. Creation of anything like optimum designs, with only a minimum amount of wind-tunnel development work, will have to wait until more basic and usable design information has become available to the aeronautical engineer.

## REFERENCES


1. Brown, R. B., Holtby, K. F., and Martin, H. C., "A Superposition Method for Calculating the Aeroelastic Behavior of Swept Wings," *Jour. Aero. Sci.*, Vol. 18, No. 8 (August, 1951). (Available as Reprint No. 54, Engineering Experiment Station, University of Washington.) See also Master's Thesis by R. B. Brown, Department of Aeronautical Engineering, University of Washington, 1951.
2. Gursahaney, H. J., and Martin, H. C., "An Observation Regarding the Deflections of Uniform Swept Cantilever Plates," *Investigations in Aeronautics*, Engineering Experiment Station Bulletin No. 118, University of Washington, 1951, p. 100.


*(Continued on page 32)*

# MASS SPECTROMETER SET UP ON CAMPUS

A. L. CRITTENDEN
*Assistant Professor of Chemical Engineering*

DURING LAST SPRING AND SUMMER, a new instrument of considerable usefulness to the research interests of the University was assembled and put into operation. The instrument is a type of mass spectrometer designed primarily for the chemical analysis of a variety of materials. It is located in Bagley Hall and is operated by the Department of Chemistry and Chemical Engineering. The equipment was built by Consolidated Engineering Corporation of Pasadena, and was financed by a number of departments of the University, including the Engineering Experiment Station. It is available for use by any interested departments.

Interest in the use of mass spectrometers for analysis arises from the ability of such instruments to discriminate, in many cases, between molecules having very similar properties and which are, therefore, difficult to separate by classical chemical methods. This situation occurs most commonly in the analysis of organic mixtures, particularly hydrocarbon mixtures, where many molecules of similar structures are present, such as mixtures of structural isomers, and mixtures of compounds of the same functional group, but having different carbon chains. A similar problem exists with mixtures of the same compound but containing molecules composed of different isotopes of the same element.

Most of the mass spectrometers built in this country are owned in the chemical industry. The petroleum industries have made particular use of the instrument's ability to separate isomers for the control of petroleum processing. The manufacturers of vacuum tubes have used the technique for analysis of residual gases in electron tubes in order to determine causes of tube failures. A mass spectrometer was used with great success in the identification of constituents in Los Angeles "smog." A relatively few such instruments are used by government laboratories and universities.

The principal uses to which the instrument has been applied at the University have been in the analysis of hydrocarbon mixtures obtained in studies of the kinetics and mechanisms of chemical reactions in the gas phase. Mass spectra have been of help in the identification of chemical structure of several new compounds first synthesized at Washington. A number of gases to be used for chemical processes have been checked for purity. An attempt to identify components in industrial waste gases has been started.

Samples introduced into the instrument are contained in a reservoir at moderate pressures and allowed to pass slowly through a carefully constructed "leak" into an ionization chamber maintained at a high vacuum (pressures about $10^{-6}$ or $10^{-7}$ millimeters of mercury). Gaseous molecules entering the ionization chamber are bombarded by a tranverse stream of electrons. Under the influence of the electron stream, many molecules are ionized to form positive ions by loss of an electron. In addition, if high energy electrons are used, considerable breaking of bonds of polyatomic molecules occurs, producing a variety of ionized and unionized fragments. Those molecules not ionized are removed from the chamber by pumps. If the numbers and kinds of ions formed can be determined, a considerable amount of information about the constitution of the entering gas can be deduced.

The nature of the positive ions formed is found by accelerating them by means of electrostatic fields and passing the ions through a uniform magnetic field. Charged particles passing through the field travel in arcs the radii of which are governed by the strength of the magnetic field, the accelerating potential used, and the mass-to-charge ratio of the ion concerned. Ions following a predetermined radius of curvature traverse 180° of arc in an evacuated tube in the magnetic field and pass through an exit slit to a collector. Ions following improper radii strike the walls of the tube, are neutralized and pumped off. By varying the accelerating potential or the magnetic field, ions of various mass-to-charge ratios can be focused on the collector. The numbers of positive ions arriving at the collector can be measured by measuring the current which flows to the collector in order to neutralize the ions. Ordinarily the accelerating potential is varied continuously and a "spectrum" of numbers of ions versus mass number is plotted by means of recording oscillographs.

In the interpretation of spectra obtained from analyses, it is necessary to know the distribution of

DR. CRITTENDEN MEASURING SAMPLE PRESSURE IN SPECTROMETER
*Left (above):* **Sample handling system;** *(below):* **Vacuum control.** *Right:* **Analyzer and magnet.**

fragments obtained for each type of molecule present in the sample. This distribution ordinarily must be obtained by running samples of the pure constituents using the same instrument. In many cases, a primary difficulty is the production of pure compounds for this purpose.

For each compound, a "cracking pattern" is obtained which is characteristic of the compound. In addition, the heights of spectrum peaks are proportional to the pressure of that compound in the reservoir. This proportionality constant must be obtained. The mass spectrum of a mixture is a summation of the individual patterns multiplied by the pressures of each individual gas in the reservoir. If the individual patterns are known, simultaneous equations may be set up to calculate the composition of mixtures from their spectra. The ability of mass spectrometers to separate isomers depends on differences in their cracking patterns.

The usual pressure of sample gases at the high pressure side of the leak is about 10 to 100 microns of mercury. Pressures lower than this can sometimes be used with less satisfactory results. Many liquids and some solids can be used as well as gases, provided that sufficient vapor pressure is available to provide the requisite pressure at the leak. Volume of gas required for samples is low; a few milliliters usually is sufficient.

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***"Ira Remsen, (a) great researcher in chemistry, said, 'There is nothing mysterious about research. Every human being, in fact every animal, is by nature engaged in research; that is to say, trying to find out something about its environment.' The late Willis R. Whitney, founder of General Electric's great research laboratory, defined it with succinct wit when he said, 'Man is the only animal who gets ahead by monkeying rather than aping.'"***

**From "Research and You," by Ralph E. Montonna, in *Refrigerating Engineering*, March, 1951.**

# Mineral Industry Institute Conference

M. S. PECHET
*Instructor in Mineral Engineering*

MORE THAN 150 MINING ENGINEERS, geologists, students, prospectors, and persons interested in the mineral industry gathered in Guggenheim Hall on February 21 for the annual meeting of the Mineral Industry Institute.

On the occasion of the 25th anniversary of the Institute, Professor Joseph Daniels opened the conference by reviewing the history of the Mineral Industry Institute and the growth of the School of Mineral Engineering since 1906. After a welcoming address by Dean Wessman, College of Engineering, University of Washington, the afternoon program opened with a paper delivered by Ernest E. Thurlow, Chief, Spokane Exploration Branch, A.E.C., on the "Domestic Sources of Radioactive Raw Materials."

Mr. Thurlow pointed out that although uranium is a minor mineral constituent, approximately one gram per ton of the earth's crust as a whole, it is apparently more abundant than such elements as gold, silver, bismuth, and mercury. The economic ores occurring in the Colorado plateau area range in grade from 0.1 to 0.4 per cent $U_3O_8$. The bulk of the world's production has been from vein deposits such as those occurring at Shinkolobwe, Belgian Congo; Joachimstahl, Czechoslovakia; Urgeirica, Portugal, and the orebodies at Great Bear Lake, Northwest Territory, Canada. The uranium deposits of secondary origin are those of the Colorado Plateau. There the Mesozoic sandstones and conglomerates contain small tabular deposits which have accounted for a substantial uranium production in the United States. The phosphorite sediments in Wyoming, Utah, Montana, and Florida contain low concentrations of uranium, but in concentrations many times that of other rocks and, with the development of metallurgical processes of recovery, they would constitute an important source of uranium.

The fear of over-expanded aluminum products is unwarranted, stated Mr. William Smith of the Kaiser Aluminum Company, in presenting his paper on "Raw Materials for the Aluminum Industry." There are strong indications the contemplated expansion will be inadequate for normal future needs. The recently discovered bauxite deposits of Jamaica will play an important role in the aluminum expansion program, and known resources are ample for at least this century. It is entirely possible that Washington coals can be utilized for the production of anodes for the electrical refining furnaces. Natural cryolite is the most critical raw material, but each major company has synthetic cryolite plants. Fluorspar will undoubtedly be the sole source of the fluorides used in the electrolyte at some future date.

The most critical factor in the production of aluminum now and in the future will be electrical energy. The only reason for the location of reduction plants in the Pacific Northwest is cheap hydroelectric power; if this should disappear, there is no attraction for prime producers of aluminum to locate in this area.

Dr. James I. Mueller, Associate Professor of Ceramic Engineering at the University of Washington, spoke to the Institute on "Critical and Strategic Materials in the Ceramic Industry." He pointed out that the majority of materials controlled by the National Production Authority's Order M-80 are of a synthetic nature; that is, they are manufactured materials. He described the materials being affected by this order, their use in industry, and what steps were being taken to make substitutes available. Throughout his talk Dr. Mueller indicated the differences in material shortages on a nation-wide basis as compared to those of the local situation.

Dr. John F. Walker, Deputy Minister of Mines, British Columbia, presented a paper on "Strategic and Critical Minerals in B. C." He compared the 1951 production of strategic and critical metals in Canada with the peak production of the war years. Except for zinc, aluminum, and cobalt, the production of these metals, including nickel, lead, copper, tungsten, tin, molybdenum, was much lower than the 1942-43 records. As for the province of British Columbia, a drop in copper output is expected in the not too distant future unless new orebodies are discovered. Lead production will increase as many lead-zinc properties are being brought into production. The Slocon area, an old silver camp, is now shaping up as a lead-zinc producer. The addition of the sink-float process at the Sullivan Mill, development of new mines in the Kootenay area, make the zinc picture very encouraging in B. C. Tungsten production

*(Continued on page 32)*

# Rotating Wetted-Wall Liquid-Liquid Extraction Using the System Normal Propanol-Tetrachlorethylene-Water*

ALBERT L. PURVIS
*Research Fellow in the Engineering Experiment Station*

THE PURPOSE OF THIS PROJECT was twofold: to investigate a ternary liquid system which could add to the already available knowledge, and to secure information on a rotating wetted-wall liquid-liquid extractor to study the effects of the flow rates of both phases and rate of revolution of the tower on the individual coefficients of mass transfer.

The physical properties of density, refractive index, and viscosity were experimentally determined on the system normal propanol-tetrachlorethylene-water at 25° C. The two-phase distribution data were correlated, and the system was found to be "solutropic."

*An abstract of the writer's thesis for the degree of Ph.D. in Chemical Engineering, November, 1951.

A rotating wetted-wall liquid extractor was designed and constructed (Fig. 1). The tower was operated at various levels of each of the two inlet rates in conjunction with a number of tower speeds. The over-all and individual transfer coefficients were calculated both on a volume and an area basis. With the aid of statistics, it was found that the heavier tetrachlorethylene phase contained the controlling resistance to mass transfer. The reciprocal of the transfer coefficients or the transfer resistance correlated very well with the reciprocal of the tetrachlorethylene flow rate to the 0.58 power and with the reciprocal of the water flow rate to the 0.20 power. Changing the column's speed of rotation apparently had no effect upon the transfer coefficients.

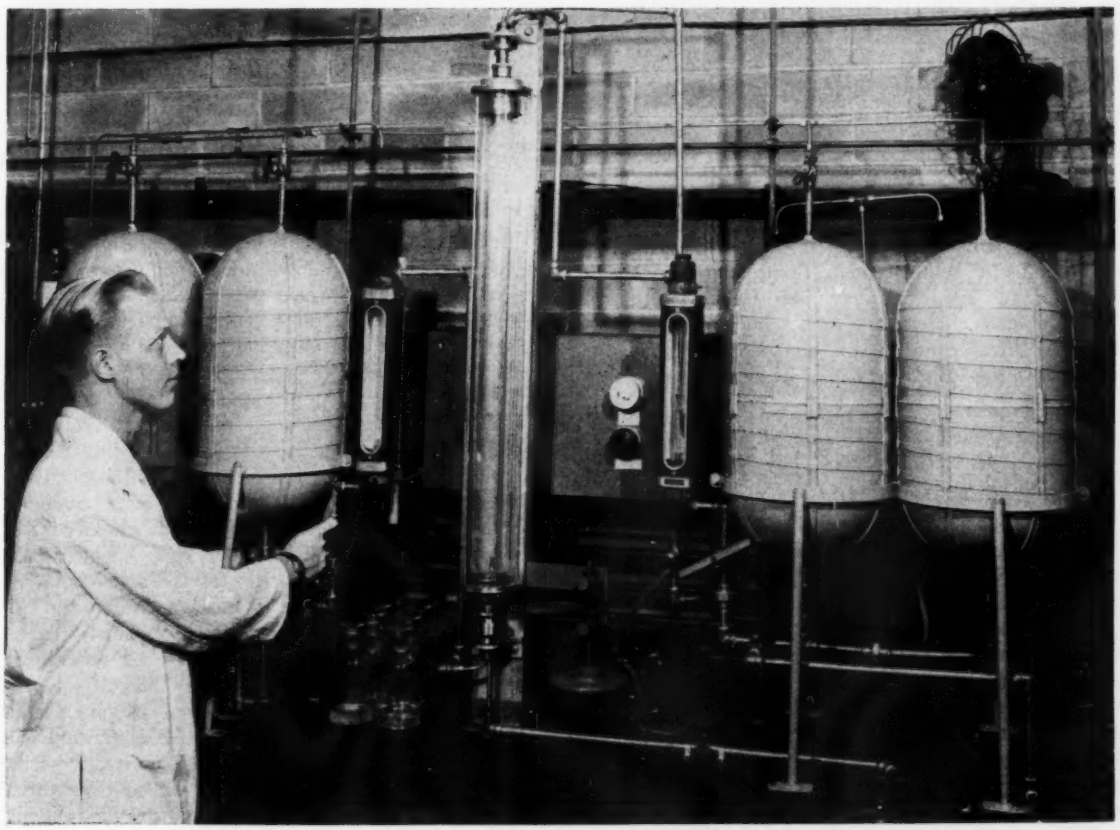

FIG. 1. DR. PURVIS WITH ROTATING WETTED-WALL LIQUID-LIQUID EXTRACTION COLUMN
(Column, 2.75 ft high and 2.92 in. in diameter, rotates at 120 rpm.)

# Engineering Research Dividends

**Recent theses for advanced degrees, which were submitted as reports on Engineering Experiment Station research projects, will regularly appear in abstract form in *The Trend*. Complete copies of these theses are available for reference at the University of Washington Library. Address inquiries to the Director of the Engineering Experiment Station.**

RATTI, D. B., "Structural Behavior of Posttensioned Concrete Beams." M.S. in Civil Engineering, 1951.

Sixteen tests of posttensioned concrete beams were made to determine their structural behavior under vertical center point loading. The beams were tested as simple beams. Reinforcing wire tensions were noted during the complete test. Strain readings of the concrete were taken at the section of maximum moment, so that stress distributions could be developed. All of the beams were constructed of concrete with an ultimate strength of 4,500 psi. The curing period was comprised of one day in the form, 25 days in an atmosphere of 100 per cent humidity and 70° F temperature, and two days in dry laboratory air. A cross section of 3¾ in. wide and six in. deep was used on all of the beams with galvanized suspension bridge wire with a diameter of 0.196 in. as the reinforcement. Span lengths of three, four, six, and eight feet were tested for both types of beams. Good correlation was achieved when the concrete stresses and beam deflections were compared with the values computed by simple theory.

WILSON, W. L., "Investigation of Heat Transfer Characteristics of an Evacuated Space." M.S. in Mechanical Engineering, 1951.

The purpose of this thesis was to determine the effect of low air pressures on the heat transfer characteristics of an air cell. The air cell consisted of two parallel flat plates separated by short spacers and sealed around the edges. An analysis was made, based on accepted equations of heat transfer and including certain boundary assumptions. The result was a quantitative prediction of the over-all heat transfer coefficient for low air pressures. The detailed analysis is set forth in the thesis, including a representative set of calculations. A procedure for shortening the time required in the trial-and-error solution of a fourth degree equation is also included. The result of the analysis was verified experimentally at 6 values of pressure ranging from atmospheric pressure to 1 millimeter of mercury. Results are shown by a curve of over-all heat transfer coefficient versus pressure. The experimental procedure is discussed in detail including explanations of some unusual features of construction and experimental technique. Drawings and diagrams pertaining to the testing equipment are included. The over-all heat transfer coefficient at 1 millimeter of mercury pressure was predicted analytically and confirmed experimentally to be approximately 50 per cent of the over-all heat transfer coefficient at atmospheric pressure.

TREFNY, R. B., "Asymptotic Approximation to the Non-Linear Behavior of Beams." M.S. in Aeronautical Engineering, 1952.

In the non-linear theory of thin elastic plates only a few solutions are known due to the difficulties associated with the governing von Kármán equations. A promising attack on such problems has recently been suggested and demonstrated for at least one case of the non-linear plate problem. The basic feature of this method is to expand certain parameters of the problem in terms of some selected constant, the resulting series being asymptotic in nature. The accuracy of this series representation is here demonstrated by considering the two-dimensional analogue to the plate problem, that is, the beam whose neutral axis is assumed to stretch under load, displacements being kept small. Comparison of the series solution with the known solution is used to exhibit the accuracy of the expansion. It is also shown that a power series does not lend itself to the attainment of a straightforward solution. The difficulty lies in satisfying the boundary conditions, although it is shown that they can be overcome. As a limiting case of the beam considered above, the asymptotic series method was used to solve the non-linear differential equation of the string. The asymptotic series, as well as a power series, yielded the exact solution for this problem of the string. A second problem, that of

considering large deflections of the cantilever beam with a concentrated load at the free end, is then investigated by the same method. In this case the neutral axis does not change length; non-linearity is due to "largeness" of curvature. Although this type of problem is fundamentally different from that of the first, the writer shows that the expansions previously used give agreement with the known solution which requires the integration of an elliptic integral.

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# Engineering Profession Defined*

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ENGINEERS ARE NOT ENGINE-MEN nor, because they take mechanics, are they mechanicians or machinists. A "radio ham," a hot-rod specialist, a plane pilot, a plumber, or any person with manual dexterity does not necessarily have engineering aptitude. What, then, is engineering? There is no universally acceptable definition, legal or otherwise. A reasonably comprehensive definition (still not entirely acceptable) would take several hundred words. The most simple definition (equally unacceptable) would define engineering as applied science. From an educational standpoint, this simple definition is relatively complete. To be an engineer, you must first understand the basic principles of physical science and then learn how to apply such principles. Accordingly, the sciences of mathematics, physics, and chemistry are the backbones of any engineering pattern. The foregoing statement does not exclude the fact that there exists an "engineering science" which the public sometimes refers to as "know how."

Engineers are dollar conscious, not from the standpoint of economics so much as from economy. Production per dollar, hence efficiency of operation, design, or construction are constant objectives.

Engineers, or more than fifty per cent of them, ultimately become management conscious. As manufacturing industry becomes more and more complex, large segments of management must be capable of understanding and controlling technical operations. Technological methods and management become an entity.

Engineering encompasses personal attributes and characteristics. Neatness, order, logical arrangements, and system are universal attributes of the persons in the profession. Engineers must appreciate human problems, personal qualities, behavior patterns, and take account of personnel in any planning. Plans cannot be built or operate without people.

Engineers work with materials. It is not sufficient to just have iron, steel, cement, non-ferrous alloys, rubber, textiles, light metals, plastics, etc. The properties of these materials must be known so that proper safety, weight, corrosion resistance, stability, and flexibility can be incorporated in a design as well as characteristics of operatability.

Engineers are concerned with energy in all forms. The history of technology development is a history of the application of energy, and much engineering is little more than the proper application of energy to materials.

A review of the foregoing statements would serve to define engineering in a simple but rather satisfactory manner. Engineers are concerned with MEN, MONEY, MANUFACTURING METHODS, MATERIALS, AND ENERGY. Obviously, they attempt to bring the four M's plus E into harmony with the immediate problem, be it the design of a bridge, the drying of hay, the cracking of oil, the speed up of a production line, the operation of a jet engine, the transmission of electric power, or the building of a boat. The basic principles are taken from science; the texts and handbooks provide the facts; education provides the understanding; and industry provides the problems.

Currently, engineering enrollment is in a decline at a time when the demand for engineering personnel exceeds any past record. There are many reasons for the decline, not the least of which is the unwillingness of students to engage in a difficult and time-consuming pattern of study. To reduce standards of instruction in engineering schools would invite disaster. Course patterns cannot turn "soft" in spite of lack of numbers because all signs point to the necessity of even "tougher" patterns if our "way of life" and our standard of living are to survive. In truth, the doings of the engineer are closely woven into our social, economic, and industrial patterns, and we are perhaps more dependent upon technology than we would care to admit.

* Reprinted from the editorial page of the *Oregon State Daily Barometer*.

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west," before the American Institute of Mining and Metallurgical Engineers which meets in Spokane, May 9-10.

**R. VON TOBEL,** joint author of the article on the analog computer in this issue, is now a research engineer with Boeing.

The national meeting of the **AMERICAN SOCIETY OF MECHANICAL ENGINEERS** was held on the University of Washington campus, March 23-26. Fields of engineering discussed during the meeting were aviation, wood industries, nuclear energy, machine design, and hydraulics.

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## NEW REPRINTS

**Reprint No. 56.** "Effects of Chemical Additions on the Hydration Rate of Fired Quicklime," H. P. Cahoon, P. D. Johnson, *Jour. Am. Cer. Soc.,* August, 1951.

**Reprint No. 57.** "Traveling Wave Relations Applicable to Power-System Fault Locators," L. J. Lewis, *Proc.,* AIEE, 1951.

**Reprint No 58.** "Contribution to the Calculation of Stresses from Photoelastic Values," D. Vasarhelyi, *Proc. Soc. Exp. Stress Anal.,* Vol. IX, No. 1 (1951).

**Reprint No. 59.** "On the Deflection of Swept Cantilevered Surfaces," H. C. Martin, H. J. Gursahaney, *Jour. Aer. Sci.,* December, 1951.

**Reprint No. 60.** "Treatment of Chromium Wastes by Ion Exchange," R. G. Tyler, W. Maske, M. J. Weston, *Sew. and Indus. Wastes,* August, 1951. "The Ozonization of Cyanide Wastes," R. G. Tyler, W. Maske, M. J. Weston, W. Matthews, *Sew. and Indus. Wastes,* September, 1951.

**Reprint No. 61.** "Differentiation of Fourier Series in Stress Solutions for Rectangular Plates," A. M. Winslow, *Quart. Jour. Mech. and App. Math.,* Vol. IV, Pt 4 (1951).

**Reprint No. 62.** "On the Dynamics of Slender Special Purpose Aircraft," R. M. Rosenberg, G. Stoner, *Jour. Aer. Sci.,* January, 1952.

**Reprint No. 63.** "Characteristics of Electric Strain Gages at Elevated Temperatures," E. E. Day, *Proc. Soc. Exp. Stress Anal.,* Vol. IX, No. 1 (1951).

**Reprint No. 64.** "Physical Interpretation of Triaxial Test Data," R. G. Hennes, C. C. Wang, *Proc.* Association of Asphalt Paving Technologists, Vol. 20, 1951.


*(Continued from page 25)*

3. MARTIN, H. C., and GURSAHANEY, H. J., "On the Deflection of Swept Cantilevered Surfaces," *Jour. Inst. Aero. Sci.,* Vol. 18, No. 12 (December, 1951). (Available as Reprint No. 59, Engineering Experiment Station, University of Washington.)
4. COLE, H. A., JR., and GANZER, V. M., "Experimental Investigation of Rolling Performance of Straight and Swept-back Flexible Wings with Various Ailerons," National Advisory Committee of Aeronautics, Technical Note 2563, December, 1951.

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*(Continued from page 28)*

is on the increase with the reopening of two mines. Aluminum output in B. C. is expected to reach one-half million tons per year on completion of the power and smelting plants at Kitimat, by the Aluminum Company of Canada. Bauxite ore from Jamaica will be used at this plant. Other critical metals as cobalt, columbum, molybdenum, and nickel do not occur in commercial quantities in the province.

E. R. Marble, manager of the Tacoma smelter of the American Smelting and Refinery Company, outlined the disparity in the world copper prices and noted that, although the copper situation is not good at the present time, within a few years it will become much better by an estimated world-wide increase of 400,000 tons per annum brought about by an expansion of present operations and the opening of new mines. The United States consumes approximately 1,400,000 tons per annum or over half of the world's copper production.

The evening program featured an address by Dr. Warren E. Hobbs, U.S.G.S. geologist for the Coeur d'Alene mining district. His subject was "Some Criteria for Mining Exploration," with general reference to the decisions and bases for judgment in clearing applications for federal aid in exploration and development of ore deposits. Dr. Hobbs pointed out that the fallacy that orebodies get bigger and richer at depth is still common in the thinking of those lacking formal mining and geological education. "The generalization is valid in just enough cases to perpetuate itself." Apart from the surface evidence pointing to the belief that an ore deposit exists, more subtle information is necessary to provide clues to the localization and finding of orebodies. Close observation of geologic structure, rock alteration and character of the gossan, are a few of the guides which are used in ore finding. Special techniques such as geophysical and geochemical methods, radioactive surveys, and ultra-light lamping may supply additional clues. Environment of the prospect is an intangible factor to be considered.

Dr. Hobbs said: "Blind drilling in most cases might have little justification, while under other circumstances may supply structural and other geological data necessary for a logical preliminary step to an extensive complex program. Exploration must have a purpose which may be the testing of a mineralized outcrop or the collecting of geological information which in itself could be an end, not an end in itself, but an end of the first step in the final completion of the program. Many exploration proposals have been rejected or completely recast because they were ill-defined and failed to present a concrete objective."

# PUBLICATIONS

*of the*

# ENGINEERING EXPERIMENT STATION

## UNIVERSITY OF WASHINGTON

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## BULLETINS

48. The Influence of Pipe Thickness on Re-Entrant Intake Losses. Charles William Harris. 35 pp. 1928.
56. Constant Flow Characteristic of the Plane Orifice in Proximity to Side Walls. Charles William Harris. 18 pp. 1931.
58. Preliminary Tests of Thirteen Washington Coals in a Powdered Coal Boiler Plant at the University of Washington. George Samuel Wilson, Harry Fagan Yancey, and Joseph Daniels. 27 pp. 1931.
60. An Electromagnetic Balance for Force Measurement of Current Control. Fred Scoville Eastman, 29 pp. 1932.
61. Hydraulic Flow Characteristics of a Square-Edged Intake. Charles William Harris. 21 pp. 1932.
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95. Hydroelectric Power in Washington. Part V, A Bibliography of Technical Papers, 1926-1935. Carl Edward Magnusson. 204 pp. 1937.
96. Hydroelectric Power in Washington. Part VI, International Boundary Waters. Carl Edward Magnusson. 17 pp. 1937.
97. Strength of Concrete for Mixes of Various Proportions. Ira Leonard Collier. 28 pp. 1938.
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116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part III, The Investigation of Models of the Original Tacoma Narrows Bridge Under the Action of Wind. F. B. Farquharson. 125 pp. 1952.
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117. Production of Wood Coke from Waste Wood. Warren L. Beuschlein. 40 pp. 1950.
118. Investigations in Aeronautics from the Department of Aeronautical Engineering. Edited by R. M. Rosenberg. 120 pp. 1951. Price: Two dollars.
119. The Extremum Principles of the Mathematical Theory of Elasticity and Their Use in Stress Analysis. (The Walker-Ames lectures of the Spring Quarter, 1950.) W. Prager (Brown University). 30 pp. 1951. Price: 75 cents.

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2. Iron and Steel Manufacture in Washington, Oregon, California, and Utah. Joseph Daniels. 69 pp. 1929.
3. Coal in Washington. Joseph Daniels. 17 pp. 1934.
4. Water Resources of Washington. Richard Gaines Tyler. 61 pp. 1938.
5. The Terminal Plan: An Improved System of Urban Transportation. Austin Vitruvius Eastman. 64 pp. 1938.
6. Chemical Utilization of the Subbituminous Coals of Washington. Lorentz A. Conradi. 83 pp. 1950.

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3. The Theory of Fractional Parts Developed for Structural Beam-Column Members Preceded by an Elementary Discussion of Simple Beam and Column Design. Sybren Ruurd Tymstra. 32 pp. 1943.
4. Gaging Chart for Horizontal Cylindrical Tanks with Flat Heads or with Convex Heads. Sybren Ruurd Tymstra. 4 pp. 1944.
5. Gaging Chart for Cylindrical Tanks with Different Types of Heads. Sybren Ruurd Tymstra. 7 pp. 1945.
6. The Heat Pump for Residential Heating. G. S. Smith, H. Christensen, and A. Presson. 23 pp. 1948.